AD-A050 765 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 14/1

IMPROVING READINESS: A COST-EFFECTIVE APPROACH.(U)

DEC 77 D D DAWSON

UNCLASSIFIED AFIT/GOR/SM/77D-4 NL

1 OF 2

AD

A050765

AD A050765

AD No.
DDC FILE COPY

1
B.S.

See back page for 1473

DDC
RECEIVED
MAR 3 1978
F

UNITED STATES AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY
Wright-Patterson Air Force Base, Ohio

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

AFIT/GOR/SM/77D-4

IMPROVING READINESS:
A COST-EFFECTIVE APPROACH

THESIS

AFIT/GOR/SM/77D-4 David D. Dawson
Capt. USA

AFIT/GOR/SM/77D-4

IMPROVING READINESS:
A COST-EFFECTIVE APPROACH

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

David D. Dawson, B.S.
Capt. USA

Graduate Operations Research
December 1977

Contents

PRECEDING PAGE BLANK - FILMED

List of Tables

Abstract

This thesis develops and demonstrates a method for improving aircraft readiness by adding specific stocks to specific bases. The effect of additional stockage on NORS is discussed. The relationship of items requisitioned as NORS to NORS aircraft is investigated using eight months of reported NORS for the A7D. Using an expression for expected NORS which is developed in the paper, a method for improving readiness is presented. The potential of the method is demonstrated using data on the F111, FB111, A7D, and B52. Increases in readiness equivalent to several additional aircraft are shown to be possible for relatively very low investments. A summary of eight months of NORS data for the F111, FB111, A7D, B52 and C135 is also included.

CHAPTER I. INTRODUCTION

The United States Air Force manages some of the most sophisticated weapons systems in the world. The funds provided to manage these systems are, of course, limited. In the face of inflation and a general redirection of priorities into areas other than defense, it is imperative that the best management possible of these funds be made.

Although the procurement cost of the Air Force weapons system is high, the operation and support costs represent an equally important part of the budget for these weapons systems. Air Force weapons as a rule have a long life expectancy. The operation and support costs over a lifetime of a weapons system is by no means small and it is in this area that substantial post-procurement savings can be made. Recognizing this, the Air Force established a special organization to search for ways in which operation and support cost savings could be made. This office, established in 1975, is known as the Productivity, Reliability, Availability and Maintainability (PRAM) Program Office. It was established to mount a focused attack on rising operational and support costs. The PRAM office determines candidates for improvement in the operation and support area. "The

criteria used in determining which of the candidates to pursue encompass the screening and selection process within PRAM policy guidelines, the practicability/feasability of the proposal, and the prioritization based upon proposed cost/savings benefits." (Ref 1:3) The importance placed by the Air Force on improvements in these areas is reflected in the PRAM budget. The PRAM budget for Fiscal Year 1976 was $7.9 million, composed of monies in the Operations and Maintenance (O&M), Research and Development (R&D) and procurement accounts (Ref 2:1).

A study recently conducted by the PRAM Program Office indicated that a large amount of readiness degradation is attributed to the supply system (Ref 3). Failure to have the right part at the right place at the right time results in a degradation in force readiness. For the 18 aircraft types involved in the PRAM study, more than two million potential flying hours were lost in 1976 as a result of a lack of spare or repair parts. This represents almost six percent of the available flying hours for these aircraft.

The purpose of this thesis is to investigate the nature of this degradation and develop a method for improvement if practicable. The presentation will begin with a discussion of some pertinent background information. Following this, the potential improvement through additional stockage will be examined. An expression to estimate Not Operationally Ready--Supply (NORS) time will be derived. Then the relationship of NORS to readiness will be examined. Finally, a method for improving readiness will be developed and its potential demonstrated.

CHAPTER II. BACKGROUND

Introduction

Items in the supply system may be classified into two basic categories--consumable and reparable. Consumable items are those which are discarded when they fail or which are used up. These items generally tend to be low dollar value items. They are also referred to as Economic Order Quantity (EOQ) items. Reparable parts are those which are repaired and placed back into service when they fail. Some of them may be irreparable, in which case they are condemned and replaced by new items. These reparable items tend to be expensive and constitute a large portion of the logistics system budget. As early as 1966, they comprised 78% of the Air Force investment in spares (Ref 4:1).

Most of the inventory models used by the Air Force are based on a two echelon inventory concept. This concept involves a depot interacting with various bases. Although there is actually more than one depot and intermediate supply sources can be considered (Ref 5), we will use the two echelon view in this study. The two echelon environment will be discussed in the next section. Following that, a discussion of the current and proposed systems for establishing stockage levels will be undertaken.

The Two Echelon Environment

The environment in which the spare parts system operates consists of two echelons. It is depicted in Fig. 1. The flows in this system will be described first for reparable items and then for consumables.

Failed items are removed from the aircraft and repaired at the base repair facility if possible. If a like item is available at the base, it is installed on the aircraft while the failed item is being repaired. In this case, once the failed item has been repaired it becomes a part of the base stock. If no like item is available, the item is returned to the aircraft after undergoing base repair. Frequently, the base repair facility will be unable to repair the item. These incidents are known as not-reparable-this-station (NRTS). A study conducted at one base for a seven month period involving 10,965 failed items found that 4905 were NRTS (Ref 6:4). NRTS items are returned to the depot for repair or condemnation. When this action is required, a demand is placed on the depot for a serviceable item. When the depot has the item in stock, it is sent to the base prior to the arrival of the failed item at the depot. If no item is in serviceable stock at the depot, the resupply is delayed until one returns from the depot repair facility. Upon arrival at the depot, the unserviceable item from the base goes through the depot repair cycle and becomes a part of the depot stock. When the serviceable item is sent to the base from the depot, it is given to the maintenance facility for replacement on the

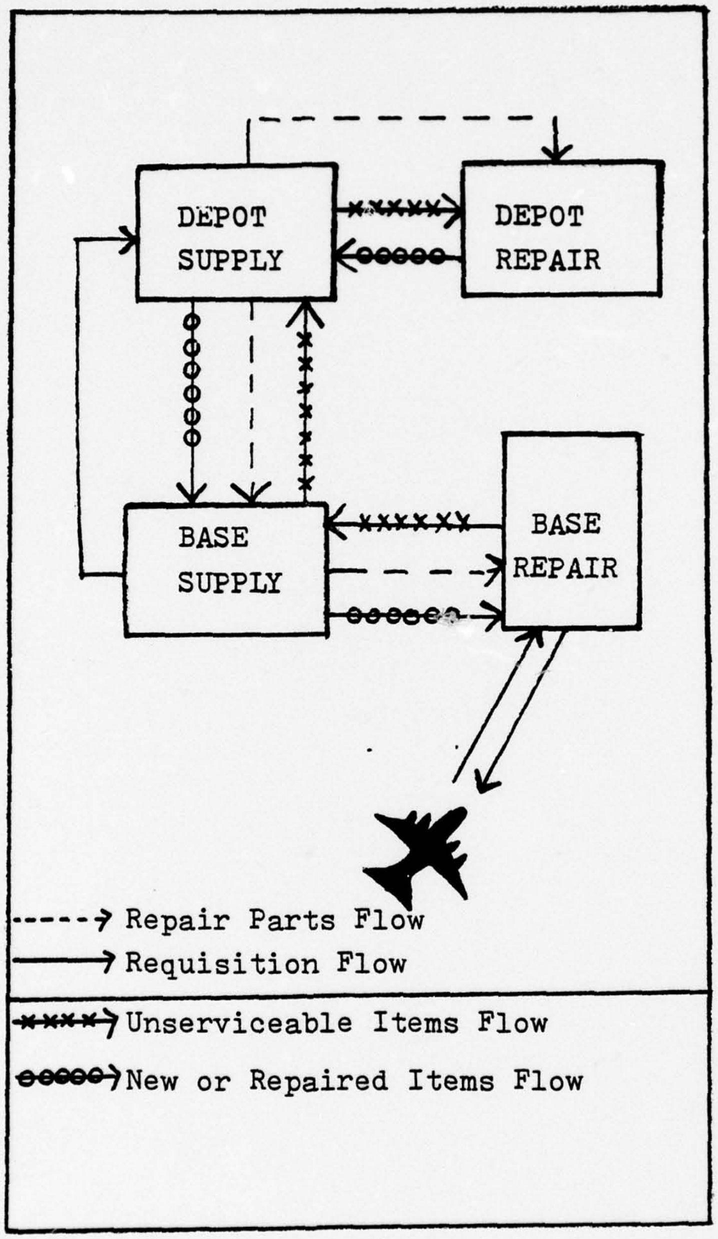

Fig. 1. Two Echelon Inventory System

aircraft. This completes the cycle for the reparable item. Consumable items can also be viewed using this two echelon concept.

If the item which failed were a consumable item, it would be disposed of. A replacement would be obtained from supply and the item replaced on the aircraft. Of course, base supply might not have the item in stock; in which case, the requirement would be passed to the depot. Even if the failed item were reparable at the base, a part required to make the repair could be consumable and would be handled as above.

The discussion thus far would indicate that the system is a closed one. This is not, in fact, the case. Consumable parts for depot stock as well as reparable items to replace those which are beyond the point of economical repair (condemnations) must be obtained. This is done through a procurement link which is external to the two echelon concept.

It should be noted that not all of the items come from the depot. Some of the items come from other services. For example, on the A7 aircraft which is common to both the Navy and Air Force, approximately 50% of the EOQ items come from Navy sources (Ref 7). Also many items which are common to multiple services are supplied by the Defense Logistics Agency.

Definition of NORS

Before discussing the systems in use by the Air Force for stock level determination, the two echelon concept just described will be used to establish some definitions which will be helpful throughout the the study. In order for an aircraft to be considered "not operationally ready-supply" (NORS), certain criteria must be met. First, the failed item must be required on the aircraft for mission performance. Secondly, the failed item must not be readily base reparable.(This includes items which the base is capable of repairing but cannot due to a lack of repair parts. This condition is known as Awaiting Parts (AWP).) Finally, the base must not have the item in stock nor be able to reasonably obtain it. Before a requisition can be processed as NORS, the Air Force Base Supply Manual requires the following:

> Efforts must be expended by stock control sections to insure that all possible sources on base are exhausted prior to submission of a NORS requisition. This will include research of other assets which may be used in lieu of the item required, search for items issued for time change, items issued as component parts/repair lists, consideration of cannibalization, and war reserve material (WRM). A NORS requisition will not be created until it has been determined that there are no assets available and that no reparables other than not-reparable-this-station (NRTS) and awaiting parts (AWP) items exist.
>
> (Ref 8:1,17,a,3)

Thus, when a NORS condition exists, it indicates that the system did not have the part available at that base even for

some other purpose.

The term NORS commonly has two different uses and some accompanying subtle differences in meaning. It is often used as an expression of readiness degradation caused by the supply system. It is in this sense of the word that we say an aircraft is NORS. On the other hand, NORS is used as an internal supply system performance measure. In this sense of the word we find NORS items. These are items which are responsible for NORS aircraft. The correspondence between NORS items and NORS aircraft is not necessarily one for one. Multiple items may have failed and be unavailable for replacement on a particular aircraft. The term NORS is used interchangeably to refer to an aircraft or items. This subtlety can be critical when NORS is used as a measure of system performance or of degradation.

NORS are subdivided into two categories. These are NORS-Flyable (NORSF) and NORS-Grounding (NORSG). A NORSF condition indicates that although the aircraft can fly, it cannot perform all of its intended missions. A NORSG condition indicates that the item causing the NORS precludes the aircraft from flying (Ref 8: 1,2,17).

<u>Reparable Item Levels</u>

This section will describe the method actually used to determine the quantity of reparables which will be authorized for stockage at any given base. This quantity is known as the requisitioning objective. It is composed of the demand level and the War Reserve Material (WRM).

The quantity of WRM necessary for a particular item is determined by the major command based on war planning/programming and separate guidance. These stocks are generally co-mingled with the peacetime stock (Ref 8:1,11,4). Their purpose is not to support day-to-day operations. Even though the stocks are co-mingled, the quantity designated as WRM is not routinely available to satisfy demands.

The remainder of the authorized stock is known as the demand level. It is comprised of three parts: the Repair Cycle Quantity, the Order and Ship Time (O&ST) Quantity and the Safety Level Quantity. Recall that in the description of the two echelon model, failed items were either returned to the depot (NRTS), condemned, or repaired at the base (RTS). The Repair Cycle Quantity is that quantity of stock necessary to meet demand while RTS items are being repaired. The Order and Ship Time Quantity is the amount of stock necessary to sustain operations for the average time required to obtain replacements from the depot for NRTS and condemned items. The Safety Level Quantity is stock authorized to offset random fluctuations in O&ST, Repair Cycle Time and demand. Fig. 2 is a graphic representation of the make-up of a base authorized stockage for any given item.

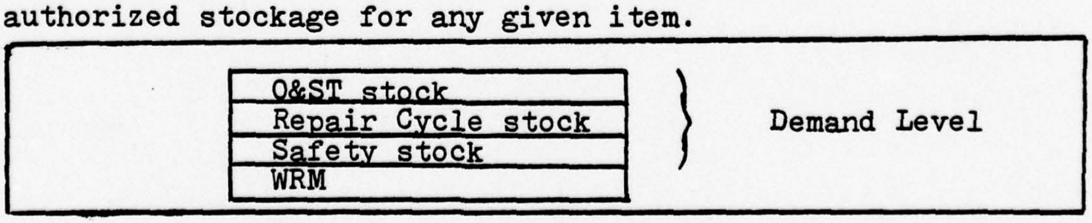

Fig. 2. Requisitioning Objective

Demand level authorization is base on the Daily Demand Rate (DDR). It is determined as follows:

$$DDR = \frac{\text{Total Demands}}{\text{\# days over which demands occurred}} \qquad (1)$$

This demand rate is based on a minimum of 180 days experience. If demand history is not available for a full 180 days, 180 will be used in the denominator "to minimize the inflationary effect" (Ref 8:1,11,f,9). The intention is to prevent stockage based on random fluctuation in demand over short periods. When more than 180 days of demand data is available, the actual number of days will be used up to 365 days. When more than one year of data is available, the most recent 365 days will be used. This demand history is maintained in six month increments for up to 18 months (Ref 8: 1,11,f,1). Total demands in the DDR computation do not include demands for initial stockage such as the demand required to bring stocks up to a newly computed level; nor does it include demands classified as non-recurring. The demand level authorization is just the sum of the Repair Cycle Quantity, the O&ST Quantity, and the Safety Level Quantity (Ref 8: 1,11,6).

$$\text{Level}=\text{RCQ}+\text{OSTQ}+\text{SLQ} \qquad (2)$$

where RCQ (Repair Cycle Quantity) =DDRxBRRxRCT
BRR (Base Repair Rate) = RTS/(RTS+NRTS+C)
C= Condemnations
RCT= Repair Cycle Time
OSTQ (Order & Ship Time Quantity=DDRx(NRTS+C)xOST
NRTS+C= 1-BRR
SLQ= Safety Level Quantity= $K\sqrt{3(RCQ+OSTQ)}$
K=1

As can be seen above, the calculation of levels requires that information on base repair times, base repair rates and O&ST be gathered. Base Repair Time (RCT) will be the average time required to repair the item or a specified maximum. These maximums are either six or nine days depending upon the type of item. Although exceptions may be made, this is the stated policy (Ref 8: 1,11,3h).

"It is Air Force policy that actual O&ST be used in computing levels." (Ref 8:1,11,5a) To compensate for the time required by the base to process these NRTS items, two days or the actual average time, if known, is added to the O&ST time (Ref 8: 1,11,5b). Thus, O&ST consists of the actual average time from order until receipt plus two days.

The procedure described above is applicable to both increasing and decreasing levels. *However, an additional* restriction is imposed to reduce a demand level to zero. To completely eliminate a demand level, there must not have been any demands in the past 180 days and the DDR must be below .0054 (Ref 8:1,11,3f). This implies that there must have been less than two demands in the previous year. In order to establish a level initially, two recurring demands must have been placed within the past 365 days (Ref 8:1,11,3f).

The frequency with which demand levels may be calculated is subject to restriction. If this were not so, the stock levels could change with each demand and a great deal of money would be wasted in constant transportation of stock to and from the depot to support changing levels.

> Changes to demand levels will not be made more frequently than once each 90 days with the following exceptions: (1)Approval of major command (2) Date of last demand exceeds 365 days for reducing a level to 0 (3) When the second demand occurs.
> (Ref 8:1,11,L)

Not all levels are calculated in this manner. Occasioally, special levels are used in lieu of the calculated levels. "Special levels provide a means whereby base stock levels may be adjusted in consideration of factors or events where usage experience is not the best predictor of future needs." (Ref 8: 1,11,8a) If, for example, a large increase in the flying hours program were planned, this might warrant the establishment of a special level. The use of special levels is discouraged unless justified since they "may result in the degradation of support to other bases whose levels are based on demand experience." (Ref 8:1,11,8g) Special levels are not necessarily additive to other authorized levels. They are a means of excluding the authorized stockage from being supported by a history of demand.

This completes the description of reparable items computation which is used by the bases to establish stockage levels. It should be noted that the procedure as described tends to dampen fluctuations in stock levels as well as the frequency of levels changes. This provides for somewhat smoother variations in these levels than might otherwise be expected.

The following section will describe the manner in which

stockage for consumable (non-reparable) items is determined.

<u>EOQ Item Levels</u>

The Air Force stocks consumable items based on the Economic Order Quantity (EOQ) concept. Under this concept, orders are given to the depot in batches. Recall that for reparable items orders were placed on the depot as soon as a level was authorized and thereafter as often as necessary to maintain that level. For consumables, the demands are accumulated into Economic Order Quantities prior to the submission of a replenishment requisition to the depot. The purpose of this is to minimize total variable cost of operations (Ref 8:1,11,Atch1).

For Repair Cycle items, the Requisitioning Objective (RO) was made up of O&ST stock, Repair Cycle stock, Safety Level stock and WRM. Only two elements are involved in the RO for EOQ items. For these items, the RO is made up of the Re-order Point Level and the Economic Order Quantity.

$$RO=ROP+EOQ \tag{3}$$

The ROP is very similar to the authorized level for Repair Cycle items. However, since consumable items, by definition, are not repaired, no expression for Repair Cycle Quantity appears in the expression.

$$ROP=OSTQ+SLQ \tag{4}$$

where OSTQ=Order and Ship Time Quantity=DDRxOST
SLQ=Safety Level Quantity=Max $\left[K\sqrt{3OSTQ}, DDRx15\right]$
K=1

The Safety Level expression alone provides for a minimum of

15 days worth of buffer stock to account for random fluctuations in demand and OST (Ref 8: 1,11,7b).

When the stock on hand falls to the re-order point, a demand is placed on the depot for replenishment. The size of this replenishment order is the Economic Order Quantity. Its value is calculated as follows:

$$\text{EOQ in dollars} = 4.4 \quad V \tag{5}$$

where V = value of annual demand = 365 x DDR x Unit Price

$$\text{and EOQ in units} = \text{Max}\left[\frac{\text{EOQ in dollars}}{\text{Unit price}}\ ;\ \text{DDR} \times 30\right]. \tag{6}$$

The meaning of the constant ,4.4, in the EOQ equation (5) is not specified in AFM 67-1. However, the Air Force EOQ policy stems from the Wilson lot size formula:

$$Q = \sqrt{\frac{2\ A\ D}{a\ c}} \tag{7}$$

where Q = Economic Order Quantity (units)
A = Ordering costs (dollars)
D = Annual demands (units/year)
a = holding cost factor
c = item cost (dollars/unit)

(Ref 9: 243-249)

Equating the Air Force formula with the Wilson lot size equation (7)

$$\text{EOQ} = \frac{4.4}{c}\sqrt{D\ c} = \sqrt{\frac{2\ A\ D}{a\ c}} \tag{8}$$

$$= \frac{1}{c}\sqrt{\frac{2\ A}{a}}\sqrt{D\ c}$$

$$4.4 = \sqrt{\frac{2\ A}{a}} \tag{9}$$

The constant in the Air Force equation is seen to be based on an assumption that the ratio of ordering costs to the holding cost factor is 9.68.

If OST and DDR were deterministic, the EOQ replenishment would appear as in Fig. 3.

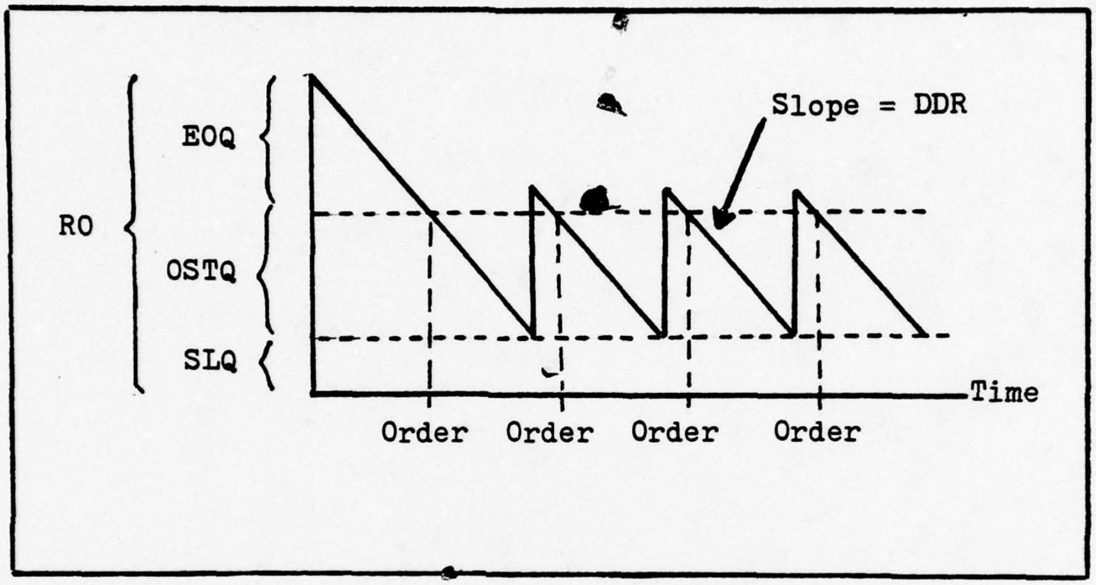

Fig. 3. EOQ Concept

Certain restrictions apply to the establishment and elimination of EOQ item stock levels (ROP's). In order to establish a demand level, a prescribed number of demands must have been recorded in the past 365 days. The required number depends on the stockage priority code (SPC). This code is used as "a decision element in determining the number of demands that an item must experience in a 365 day time period prior to the establishment of a demand level" (Ref 10: 2,11,19). SPC's are assigned on the basis of urgency of need; any item which had caused a NORS condition would be assigned an SPC of 1. The number of demands re-

quired in the last 365 days by Stockage Priority Code (SPC) is as shown in Table I.

Table I

Stockage Priority Codes

SPC	DMDS
1	3
2	4
3	4
4	6
5	6

(Ref 8:1,11,17)

An EOQ item may be eliminated from stock whenever there have been no demands reported in the past year.

> Demand levels and re-order levels for EOQ items will be recomputed once each 90 days or when:
> 1) the re-order level is reached 2) the date of last demand exceeds 365 days 3) the item qualifies for stockage (as described above) 4) directed by the major command.
> (Ref 8:1,11,31)

The EOQ and reparable items computations presented here represent the logic by which base stock levels are determined. The actual calculations are made using an automated system at the base. Although cost is a factor in determining the Economic Order Quantity, neither EOQ nor reparable item levels calculations give consideration to cost. Thus the systems currently used for establishing authorized base levels do not provide the maximum support possible from a given level of investment. Some other scheme of stockage might be able to provide more support from the same investment.

We will next examine a method which is capable of providing the maximum amount of one measure of support for a specified investment.

METRIC

The Multi-Echelon Technique for Recoverable Item Control (METRIC) was designed for the Air Force by the RAND Corp. (Ref 4). Its "purpose is to optimize system performance for specified levels of system investment" (Ref 4:2). The technique used in METRIC has been applied to many more complex follow on systems (Ref 5, Ref 11, Ref 12). A derivative of METRIC known as the D028 has been proposed for establishing stock levels at the bases (Ref 13). Since METRIC is the basic technique used in these systems, a brief review of some of its features will be instructive.

METRIC attempts to minimize the sum of expected backorders for all items at all bases subject to a budget constraint. The term backorder as used by RAND means that there is an "unstaisfied demand at base level, e.g. a recoverable item is missing from an aircraft." (Ref 4:6) The Air Force definition of backorder is " an obligation, assumed and recorded by any supply echelon, to issue at a subsequent date a requisitioned item which was not immediately available for supply." (Ref 8: 1-9) METRIC restricts the Air Force definition to the lowest echelon.

The backorder criteria which METRIC optimizes is the expected value of the number of backorders in existence at a random point in time.

$$B(s) = \sum_{X=s+1}^{\infty} (X-s)P(X|\lambda T) \qquad (10)$$

where $B(s)$ = expected backorders as a function of stock level
s = the level of stocks
$P(X|\lambda T)$ = the compound Poisson probability density for a mean customer rate λT
(Ref 4:14)

The optimization problem solved by METRIC is

$$\text{Minimize} \quad \sum_i \sum_j B\,(S_{ij}) \qquad (11)$$

Subject to

$$C_i \; S_{ij} = K \qquad (12)$$

$$i = 0,1,2,\ldots n$$
$$j = 0,1,2,\ldots m$$

where S_{ij} = stock of item i at base j
C_i = unit cost of ith item
$B\,(S_{ij})$ = expected backorders for the ith part at base j
K = budget limitation.

The solution to this problem is obtained by calculating expected backorders for all combinations of stockage among the bases and depot. Following this, a marginal allocation of items to locations is made on the basis of maximum reduction in backorders per dollar invested. Although this technique will minimize expected backorders for a given budget, the effect of this on aircraft readiness is not clear.

NORS vs Backorders

If all items were essential for mission performance, then every backorder would result in a NORS condition on an aircraft (either NORSF or NORSG). However, because of the strict requirements a requisition must meet to be classified as NORS, every backorder does not result in a NORS requisition. The necessary requirements for a requisition to be classified as NORS were explained earlier in the definitions of NORS. Since an item must not be available on the base--even in base repair--the part may be missing from the aircraft for a period equal to the base repair cycle time without causing a NORS as reported in the supply system.

If all items were essential for mission performance, (i.e. no redundancies or non-mission essential equipment), then every backorder would result in aircraft readiness degradation. However, every backorder would not result in a NORS requisition. Recall from the definition of NORS that strict requirements must be met before an item is ordered as NORS. An item may be missing from an aircraft, (a backorder exists), but if the item can be repaired at the base without ordering repair parts, the supply system would not record a NORS. It should be pointed out that for readiness reporting, this time would also not be recorded as NORS time. Because the required part was being repaired at the base, the associated aircraft would be classified as Not Operationally Ready-Maintenance (NORM).

The backorder as a measure of supply system performance

overlaps two readiness measures--NORS and NORM. The supply measure, NORS, and the readiness measure, NORS, are the same.

This concludes the presentation of background material. With a basic understanding of base level stocking policy and NORS, we can now pursue a means for improving readiness.

CHAPTER III. STOCKING TO PREVENT NORS

Introduction

When methods for improving aircraft availability via the supply system are considered, various approaches are available. Some of these are: 1) decrease order and ship time, 2) decrease depot repair cycle time, 3) increase depot stockage, 4) increase base stockage. It is the latter area, increasing base stockage, which this study will consider.

Of course, if there were an unlimited supply of all items at every base, there would be no NORS problem. Unfortunately, the reality of budget limitations negates this possibility. Any improvement in NORS through additional stockage requires that the benefit derived be of greater value than the cost of the additional stockage. This chapter will provide a basic understanding of the way in which the addition of items at bases reduces the expected aircraft degradation.

The Impact of Additional Stockage

Numerous measures of supply system performance are available. In this section we will examine the impact of additional stockage on two of these measures--backorders

and NORS.

A NORS condition at a base for a single item has been hypothetically constructed for a six day period in Fig. 4. Each shaded block in the figure represents a NORS condition for one aircraft as reported for the six day period. Counting the number of quarter days in which 0,1, and 2 aircraft are down, it is possible to determine the degradation attributable to this item. For the situation depicted in the top half of Fig. 4, this degradation is as shown in Table II.

Table II

Initial Aircraft Degradation

# of aircraft down	% of period
0	5/24
1	10/24
2	7/24
3	2/24

Now if an additional item had been available at the beginning of the six day period, the NORS condition would have been as depicted in the lower half of Fig. 4. The unit which normally would have been used to alleviate the first NORS situation can now be used to prevent the second NORS condition and so forth throughout the period. The result is that the percentage of time for which no aircraft are down increases by 10/24. This is an improvement equal to the percentage of time for which one aircraft was down prior to the addition of the extra part. The resultant degradation after adding the additional part can be seen in

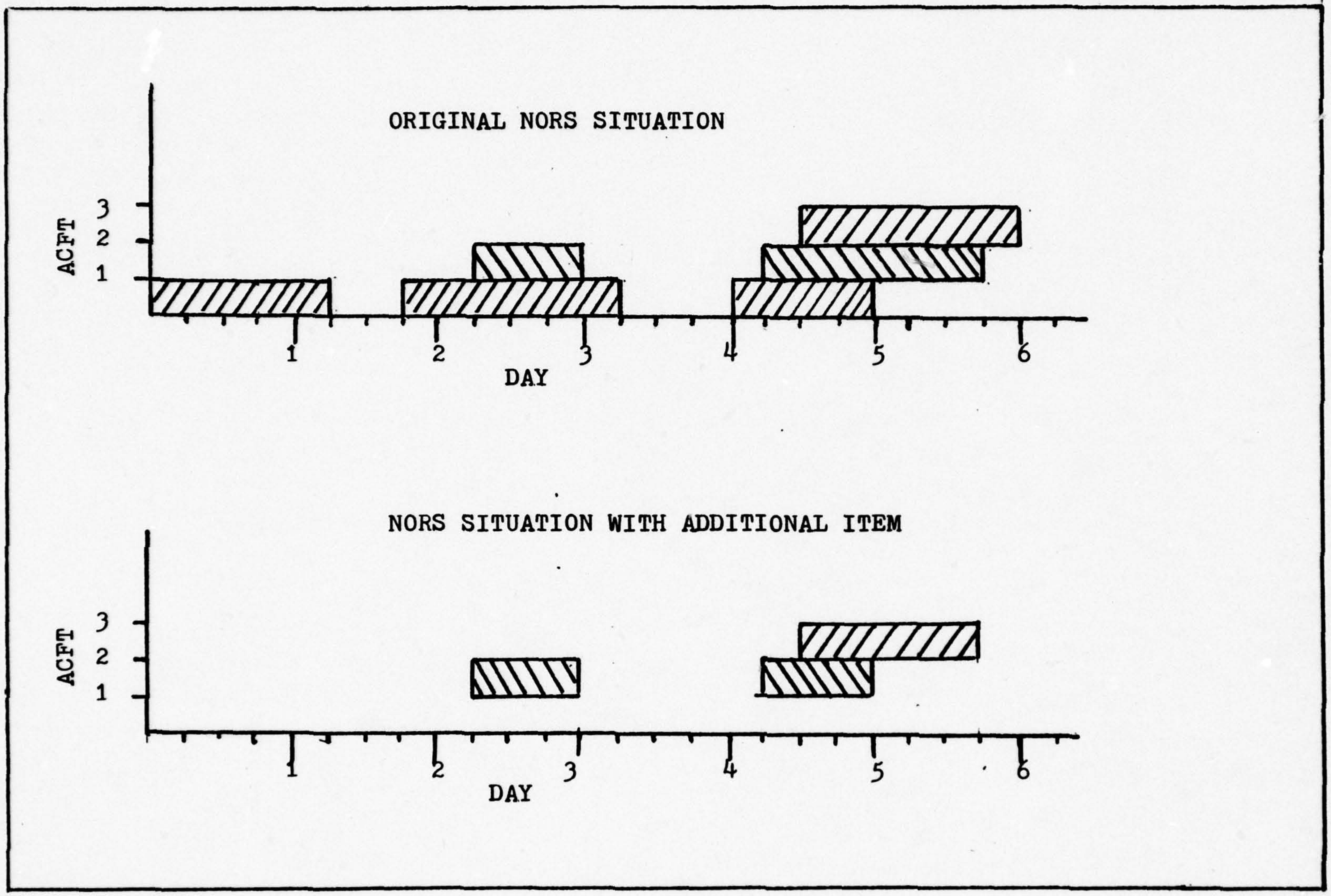

Fig. 4. Hypothetical NORS Situation

Table III.

Table III
Degradation After Adding Item

# of aircraft down	% of period
0	15/24
1	7/24
2	2/24
3	0

The same reasoning leads to the potential benefits in terms of increased aircraft availability for the addition of two, three, etc. parts.

<u>Expected Backorders</u>

A measure of supply system performance similar to item NORS is base backorders. This is the measure used in the Multi Echelon Technique for Recoverable Item Control (METRIC) (Ref 4) which is the basis for the Air Force D041 Requirements Computation System. As defined for METRIC, " a backorder exists at a point in time if, and only if, there is an unsatisfied demand at base level,e.g. a recoverable item is missing on an aircraft." (Ref 4:6) The METRIC expression for backorders at a base at a random point in time is

$$B\,(S) = \sum_{X=s+1}^{\infty}(X-S)P(X\,|\,\lambda\,T) \qquad (13)$$

where S is the base stock level and $P(X|\lambda T)$ is the probability distribution of demands which relate to backorders. $P(X|\lambda T)$ is not a function of the base stock level (S) for the item. Now if we stock an additional item at

the base, we can use this expression to determine the corresponding change in backorders:

$$B(S+1)-B(S) = \sum_{X=S+2}^{\infty}(X-S-1)P(X|\lambda T) - \sum_{X=S+1}^{\infty}(X-S)P(X|\lambda T) \quad (14)$$

$$= P(S+2)+2P(S+3)+3P(S+4)+4P(S+5)+\ldots- P(S+1)-2P(S+2)-3P(S+3)-4P(S+4)-\ldots$$

$$= -\sum_{i=1}^{\infty} P(S+i)$$

So the gain in expected backorders made by stocking one extra part would be equal to the sum of the probabilities of there being 1,2,etc. backorders prior to the addition of the part. By similar reasoning, we find that the benefit, in expected backorder terms, for stocking two extra parts is

$$B(S+2)-B(S) = -\left[\sum_{i=1}^{\infty}P(S+i) \pm \sum_{i=2}^{\infty}P(S+i)\right] \quad (15)$$

or the probability of there being any backorders before the addition of the items plus the probability of there being two or more. The benefit of adding the kth part, then, is just

$$-\sum_{i=k}^{\infty}P(S+i) \quad (16)$$

<u>Expected</u> <u>NORS</u>

To obtain a practical appreciation for these results we will again use Fig.4.

If we regard the top half of Fig. 4. as a probabliity distribution for NORS, we have the distribution shown in Table IV just as before.

Table IV

NORS Probability Distribution

# NORS	Prob.
0	5/24
1	10/24
2	7/24
3	2/24

Taking the expectation of this distribution, we find

$$E(NORS) = 0(5/24)+1(10/24)+2(7/24)+3(2/24) = 30/24 \tag{17}$$

After adding an additional item, the preceding discussion would indicate that the improvement in expected NORS should be

$$P(NORS \geq 1) = 10/24+7/24+2/24 = 19/24 \tag{18}$$

Table V represents the distribution of NORS after adding the part.

Table V

P(NORS) With Additional Part

#NORS	Prob.
0	15/24
1	7/24
2	2/24

Taking the expectation, we find

$$E(NORS) = 1(7/24)+2(2/24) = 11/24 \tag{19}$$

which is an improvement in the expected number of NORS air-

craft of 30/24-11/24 = 19/24 as suggested (Eq 18).

This discussion has shown that if we know the NORS posture, as in the example above, or the backorder posture, as in the earlier analytical example, then we can make statements about what that posture would be if we stocked an additional quantity of a given item at a base. It would seem that all we need then is a means of reconstructing the NORS history for each item at each base. With this information we could begin to make improvements. In doing so, we would not want to stock against abnormal occurrences. If an increase in NORS were due to a temporary increase in depot repair cycle time, for example, it would not be wise to stock an additional item at the base. By the time we learned of the increase in depot repair time through reported NORS and decided to increase stockage, the repair cycle time could be back to normal. Likewise, we would not want to observe a limited period of NORS and stock against the high part of a cycle. Thus, we must limit the search to items for which a level is stocked that allows NORS to persist.

The NORS which additional stockage must remove is what we shall call the ambient NORS levels. This is a level of NORS which would exist even if there were no anomalies in the response time by the depot. This is the NORS which base stockage policy allows to exist.

Investigation of NORS Data

In order to examine the ambient NORS level, NORS data covering an eight month period for the A7D aircraft was used. This data represented every item NORS event which had been terminated during the period 1 Oct 1976 through 31 May 1977. The data was collected from the D165B depot level data system.

In order to determine whether an ambient level could be discerned, the data was divided into three parts corresponding to the quarters of the year. Then for each stock numbered item reported, the number of NORS occurrences in each quarter was counted. An ambient level was defined to exist if there was at least one NORS in the fourth quarter of 1976 and one in the second quarter of 1977. This definition was used to see to what degree the data reflected persistent or ambient NORS problems. Table VI shows the results of this examination for bases reporting NORS on ten or more different stock numbers (NSN's). The bases are represented by the supply account code from the document number of the NORS requisition as reported in the D165 data system.

An average of less than two percent of the stock numbers causing NORS passed this test for ambient levels. The highest level of ambient NORS was at FB4877 where 6.8% of the items passed the test. If there were truly an ambient level reflected in the data, a larger quantity of the items would be expected to have passed the test. It is

conceivable that many of these which did pass are simply the items for which the depot is experiencing unusual repair or procurement problems. This test indicated that if an ambient level were present, it was not readily evident in the data.

Table VI

NORS Behavior

Base	# NSNs Passing Ambient Level Test	# NSNs Failing Ambient Level Test
FB2586	0	11
FB2805	0	72
FB2823	1	31
FB4604	0	22
Fb4805	11	316
FB4806	11	326
FB4810	1	37
FB4852	0	36
FB4877	22	322
FB5260	0	107
FB6022	4	75
FB6061	3	118
FB6141	0	50
FB6311	3	165
FB6354	0	128
FB6381	2	154
FB6401	1	87
FB6540	0	87

If many of the items had very low demand rates, eight months of data might be insufficient to detect an ambient NORS level. The initial screening of the A7 data indicated that 31.3% of the NORS incidents were caused by items which the bases did not stock. We know from base stockage policy that an item must have had two demands in 365 days to qualify for stockage. Thus, this 31.3% of the NORS events were caused by items which were recorded in the

base supply system as having a daily demand rate of less than 0.0054. Further investigation of the A7 data showed that non-stock items accounted for 1481 of 1768 different NSN's causing NORSG events. Since a very insignificant part of the reported NORS was a result of low demand items, a very large amount of data would have to be obtained to approach the ambient level from the standpoint of a reconstruction of NORS history.

It has been shown that if the future NORS could be estimated, a predictable improvement could be made by additional stockage. It has also been shown that a determination of expected NORS cannot be had from the eight months of data which was examined. Although we cannot obtain an empirical estimate for expected NORS from only eight months of data, as explained, another alternative is available. The next chapter will discuss the development of an analytical expression for expected NORS.

CHAPTER IV.

DETERMINATION OF EXPECTED NORS

Introduction

It has now been demonstrated that if item NORS events could be predicted accurately, additional stocks could be used to reduce or eliminate these occurrences. Furthermore, the exact reduction in NORS could be determined prior to addition of stocks. If this could be related to readiness, it would permit the allocation of funds to additional stockage in an optimal way. It was also demonstrated that empirical NORS data was not an accurate source of information on the underlying or ambient NORS level. It is only this ambient level which would be expected to exist at some future time. Thus, a method for predicting the expected NORS is needed.

We will require that the expression for expected NORS correspond to the Air Force definition used in classifying a requisition as NORS. Recall that this classification excluded items in the repair cycle (except those classified AWP). We shall define a NORS as a condition in which an item is demanded; the item is NRTS; and either no level is authorized or the stocks authorized are not available.

Derivation of the Expression for Expected NORS

The stock to support the authorized level may be in one of three places: on hand, on order, or in maintenance.

$$\text{Level} = \text{On hand} + \text{On order} + \text{In maintenance} \tag{20}$$

By definition, we know that a NORS exists when the non-reparable demand at some point in time is greater than the available stock at the base excluding that in repair.

Thus, NORS = 1 when $D_N(t) = L - Q_0(t) + 1$ (21)

$D_N(t)$ = NORS demand at time t
L = authorized stock level
$Q_0(t)$ = quantity on order at time t

Then NORS = n when $D_N(t) = L - Q_0(t) + n$ (22)

so $P(\text{NORS} = n) = P\left[D_N(t) + Q_0(t)\right] = L + n.$ (23)

Now if we assume that the mean time between failures (MTBF) of an item is distributed according to an exponential distribution with mean $1/\nu$, then the number of failures of that item per unit time has a Poisson distribution with mean ν. When the failures of n like items are pooled to determine the demand at the base, this demand is also distributed as a Poisson distribution. The mean of this base demand distribution is simply the sum of the means of the individual item demand distributions or $n\nu$. We shall call this the Daily Demand Rate (λ).

If N% of the failed items are not base reparable, then the average rate of items returned to the depot is $N\lambda$.

We will assume that this is also represented by a Poisson process. Then the probability that the demand is X in a given period of time t is

$$P(D_N = X) = \frac{(N\lambda t)^X e^{-N\lambda t}}{X!} \tag{24}$$

If the time to satisfy a NRTS demand is θ then any demands which occurred earlier than t-θ will have been satisfied by t. Thus, only the demands occurring between t and t-θ can cause NORS. The probability of a NORS can now be expressed as

$$\begin{aligned} P(NORS=n) &= P\left[D_N(t-\theta, t) = L+n\right] \\ &= \frac{(N\lambda\theta)^{L+n} e^{-N\lambda\theta}}{(L+n)!} \end{aligned} \tag{25}$$

From this we obtain the following expression for expected NORS

$$E(NORS) = \sum_{n=1}^{\infty} \frac{n(N\lambda\theta)^{L+n} e^{-N\lambda\theta}}{(L+n)!} \tag{26}$$

This expression represents the expected number of items reported as NORS on a given day. This does not represent the numberof NORS occurrences on a given day but the number of NORS requisitions outstanding.

Now, if we know the daily demand rate (λ), the NRTS rate (N), the average time to satisfy a demand (θ), and the base stock level L we have a means of arriving at the ambient NORS level. For items which experience delay at the depot, θ will be greater than OST; but for many items for which the NORS is terminated by other than depot action (Table XI), θ will be less than OST. Therefore, OST will be used as an approximation for θ. As a result of a theorem attributed to Palm(Ref 14:392) it is not necessary that θ be deterministic. If we know the mean of θ the same result is obtained in the steady state.

Base Levels

We cannot know L exactly for each base. However, since we know the base stocking policy, we have a means of estimating its value. From equation (2)

$$L = \lambda(N\theta+(1-N)R) + \sqrt{3\,\lambda(N\theta+(1-N)R)} \qquad (27)$$

where R = Base Repair Cycle Time (RCT)
λ = Daily Demand Rate
θ = OST
N = NRTS rate
L = base stock level

With these expressions (Eq 26, Eq 27), the value of expected NORS can be calculated. Fig. 10. is a plot of expected NORS days per year (E(NORS)$\cdot$365) as a function of Daily Demand Rate. As Daily Demand Rate increases, the expected NORS is seen to rise to a maximum and then decrease sharply. The points where the sharp decreases occur are those where the base stock levels increase by one. This demonstrates the effect of adding additional stocks at the base. Figure 5. depicts the behavior of expected NORS for an item with a low NRTS rate. In this case, the base stocking policy is seen to do a good job of preventing NORS after the item qualifies for stockage.

NORS Sensitivity Analysis

Figures 5,6,7,8 and 9 show the sensitivity of expected NORS to NRTS rate. As the NRTS rate increases, the value of expected NORS displays a wider variation. (Note that there is a change of scale between Figs. 5 and 6 and between Figs. 6 and 7.) When demand rate is low--until the item qualifies for base stockage--the expected NORS is equivalent to the

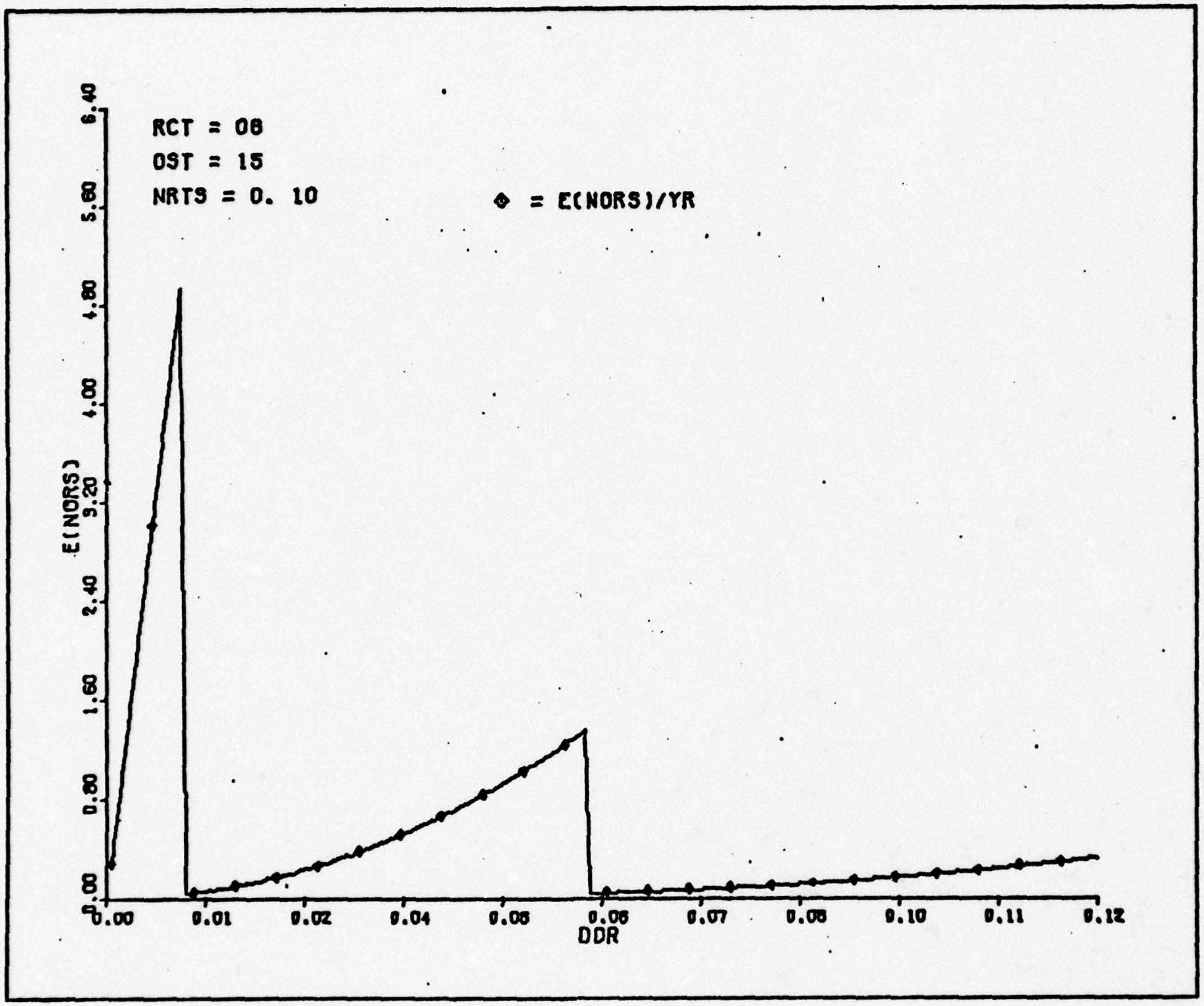

Fig. 5. Expected NORS (NRTS ≐ 0.10)

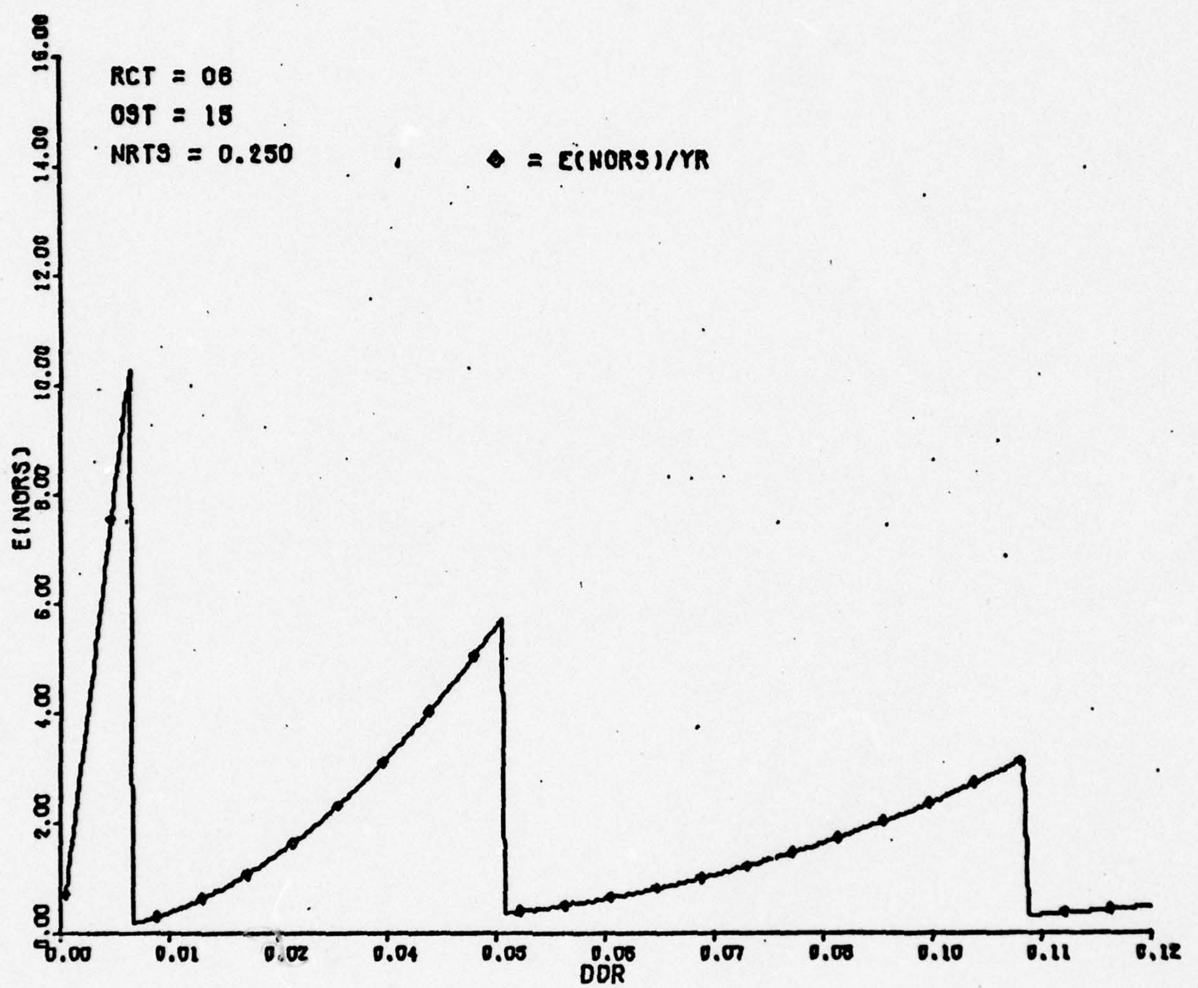

Fig. 6. Expected NORS (NRTS = 0.250)

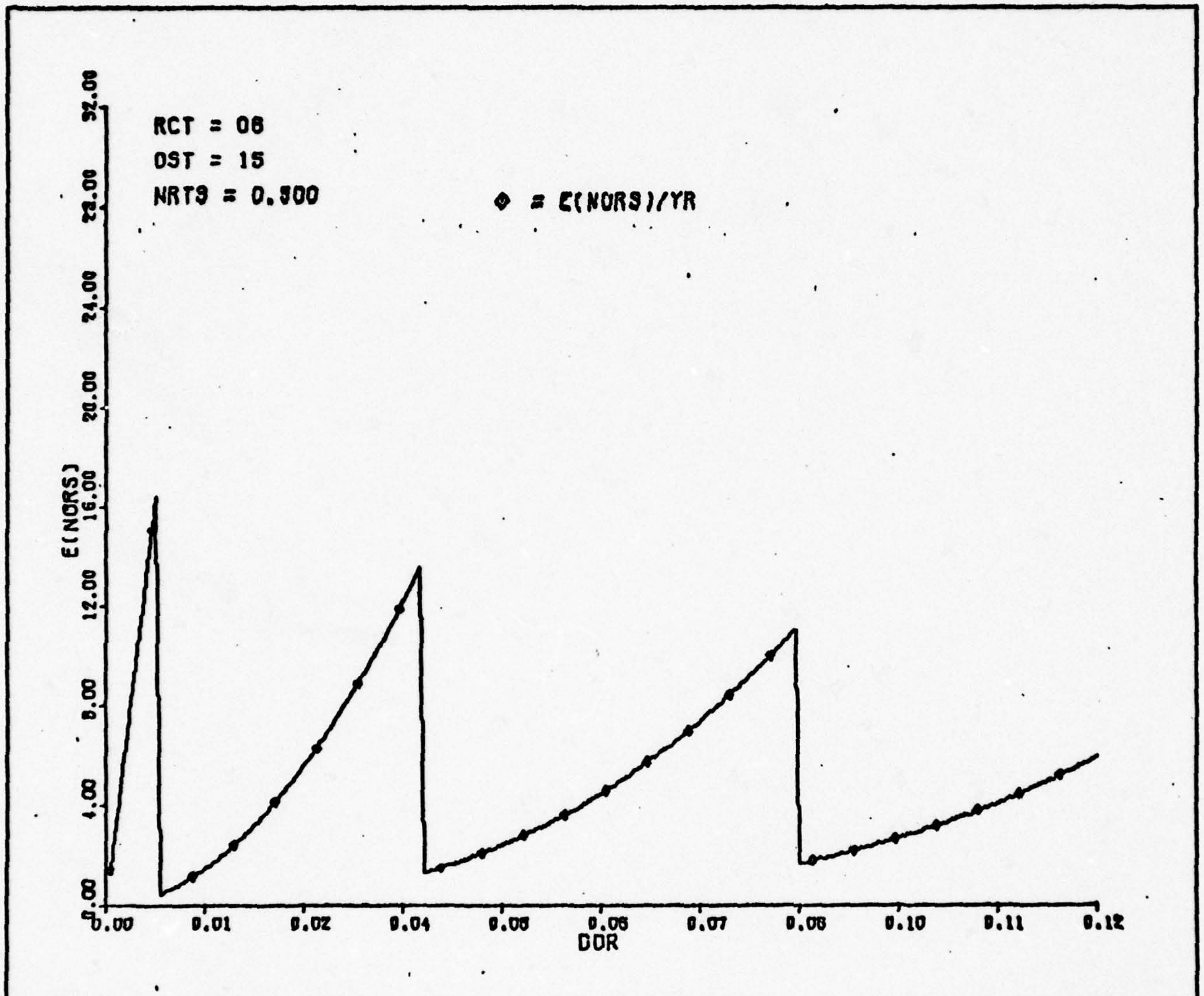

Fig. 7. Expected NORS (NRTS = 0.500)

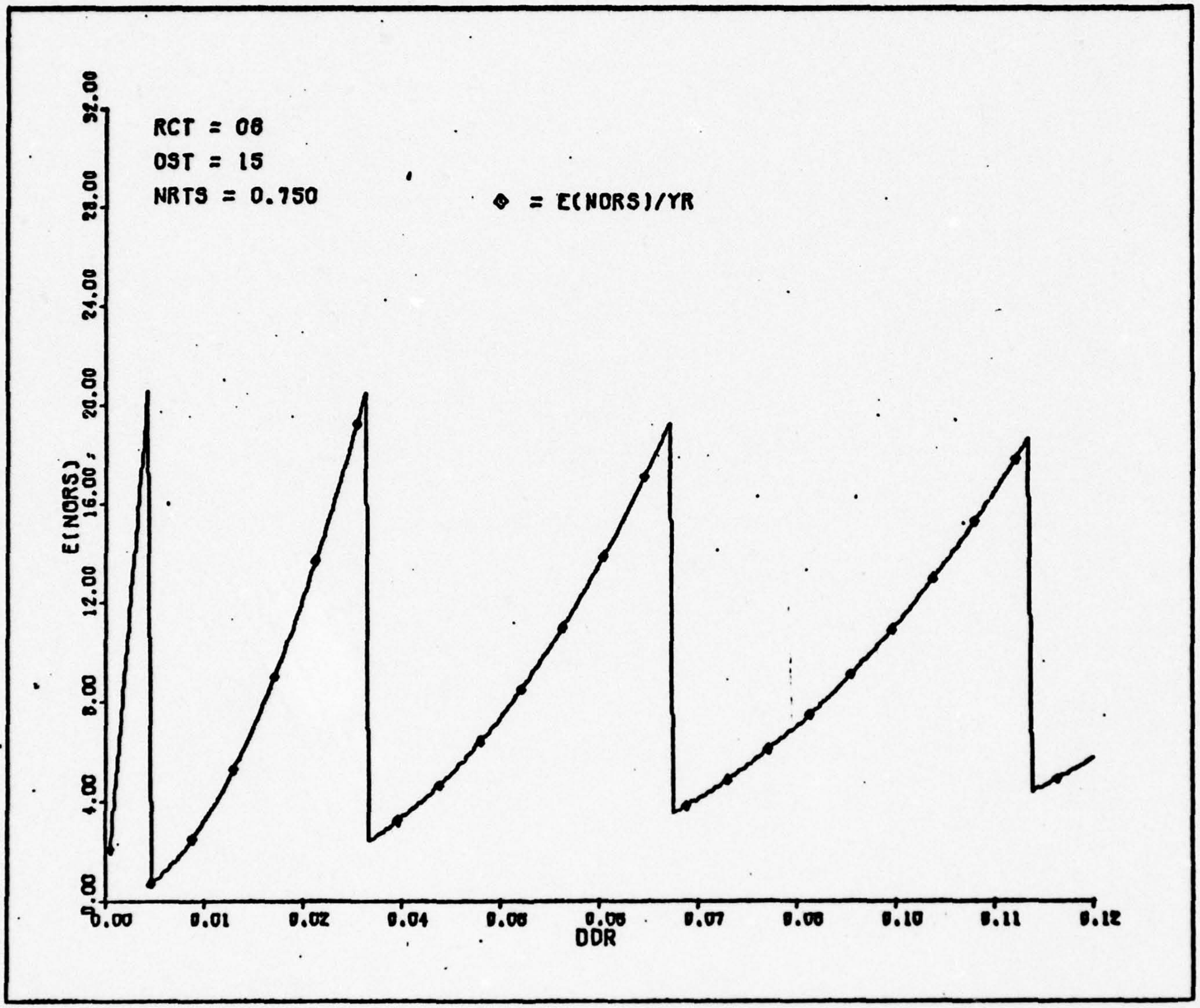

Fig. 8. Expected NORS (NRTS = 0.750)

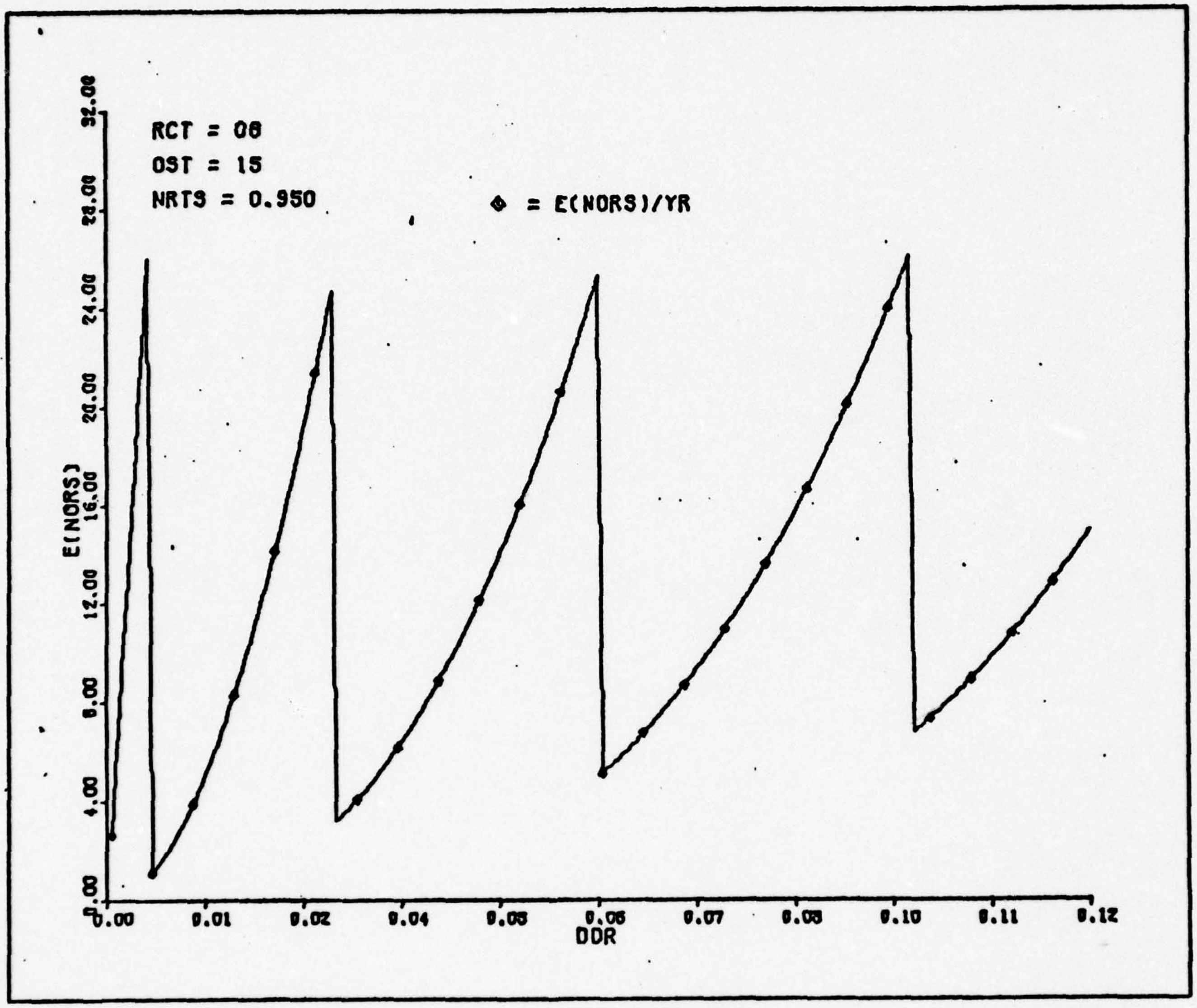

Fig. 9. Expected NORS (NRTS = 0.950)

portion of daily demand which is NRTS. Notice from the expression for expected NORS (Eq 26) that, when L is 0, the expected value is just that of the Poisson distribution or $N\lambda\theta$. Thus, expected NORS for non-stocked items is simply the NRTS demand ($N\lambda$) which has occurred in the last θ days.

The effect of increasing Order and Ship time was also examined. In Figure 10, the Order and Ship time has been increased to 31 days from its previous value of 15. The other parameters in Fig. 10 are the same as they were in Fig. 6. Notice in Fig. 10 that the expected NORS has increased for all DDR. Also, more changes in base stock levels are observed.

In general, the base stockage policy works better for items with low NRTS than for ones with high NRTS rates. Furthermore, this analysis indicates that the base stockage policy provides more protection for items with low OST than it does for items which have high OST. Although graphs are not presented here, the effect of RCT on NORS is much less than that of OST. Notice that RCT appears in the expected NORS equation (Eq 26) only as an element in determining base stock levels. The range of interest of RCT is generally smaller than is the range for OST values. AFM 67-1 defines default values for RCT when actual values are not known. These default values, as explained in the background discussion, are either 6 or 9 days. Standards for OST, as defined by AFM 67-1, range from 8 to 31 days (Ref 8: Atch A-3).

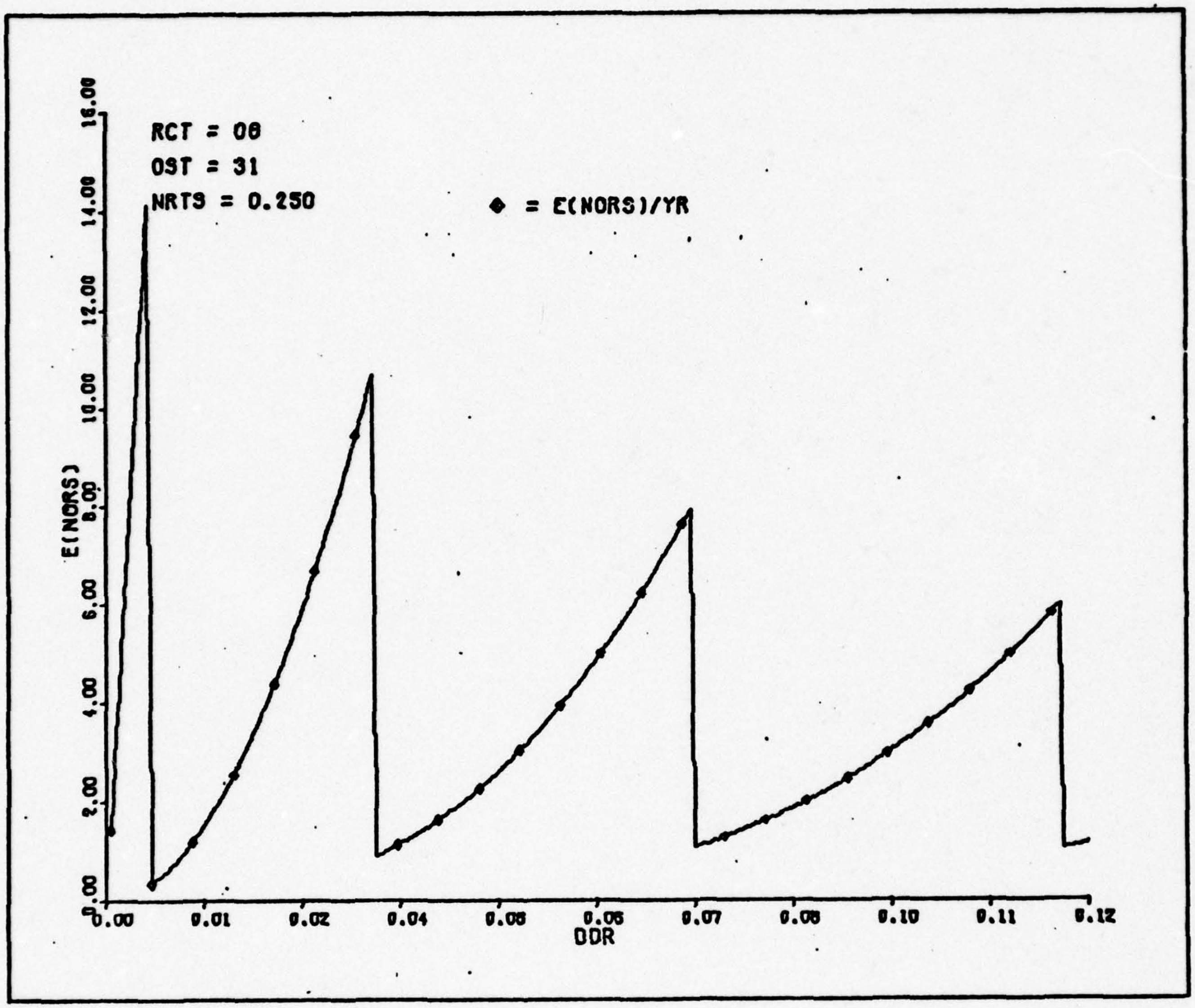

Fig. 10. Expected NORS (OST = 31)

Using the expression developed above for NORS, we can now estimate the potential for improvement as a result of adding stocks. This improvement is the difference between expected NORS when an additional part is added and expected NORS prior to the addition.

$$B_i = E(NORS|S=L+i-1) - E(NORS|S=L+i) \tag{28}$$

where B_i = Benefit from adding the ith part
S = Total base stock level
L = Estimated base stock level
$i = 1,2,\ldots$

With this expression for expected benefit, a marginal analysis could be used to obtain the maximum benefit for a given investment.

Since levels and demand rates would be different for each item at each base, the benefit would have to be determined by item by base. Once this has been done, the benefit is divided by the price, to place all items in terms of benefit/dollar invested. Then we begin to invest. The first item selected is the one having the highest benefit per dollar and so on until the budget constraint is reached. This procedure provides the maximum return on investment.

We now have an optimal procedure to reduce NORS through additional stockage. The NORS to which the method applies is the type we have referred to as item NORS. Since the relationship of these NORS to operational aircraft is not readily apparent, an investigation of this relation will be made in the following chapter.

CHAPTER V.

NORS AS A MEASURE OF READINESS

Quite often, management focus is placed on the reduction of NORS. The goal of these efforts is to improve fleet readiness. In order to obtain this goal, NORS as a measure of supply system performance is frequently used. This chapter will investigate the comparison of the goal of improvement in NORS as used by the logistician with NORS as used by those concerned with overall fleet readiness.

When an aircraft is not operationally ready, some impairment in mission performance capability is indicated. If this impairment is for want of a spare part, the aircraft is called NORS. Likewise, the requisition for the needed item is known as a NORS requisition. NORS conditions may be either flyable (NORSF) or grounding (NORSG). If they are grounding, then all mission capability of the aircraft is lost. Flyable NORS, however, indicates only a partial mission deterioration.

When an aircraft is NORSG, it cannot perform any of its missions. As far as mission capability is concerned, it makes no difference whether the condition is caused by one part or ten. Exactly one aircraft will not be operation-

al until the needed items are obtained. If there were ten items missing, the supply system would be concerned with ten NORS items while the readiness system would indicate only one NORS aircraft.

NORSF as a measure of readiness is not as straightforward as is NORSG. The relationship is similar in that multiple items may be causing the reporting of one NORS aircraft. However, the amount of readiness degradation caused by a particular NORSF item is not as clear as with NORSG. If one item is NORSG on an aircraft, then it is certain that the aircraft degradation attributable to that item is the "worth" of one aircraft. All that can be said about NORSF is that the degradation is something less than one aircraft. The situation becomes even more complicated when two or more items are both missing from an aircraft. If the items are both grounding, they can be thought to contribute equal amounts to the degradation. However, if they are NORSF, then it is difficult to determine exactly what the degradation attributable to each is. Since more than one NORSF condition can exist simultaneously on the same aircraft, the allocation of degradation (were some known percentage of aircraft worth associated with a particular mission capability) to a particular item can be only arbitrary.

Using eight months of NORS requisition history for the A7D aircraft, the relationship between grounded aircraft and NORS items was investigated. Figure 11 shows an example of a situation in which a single aircraft (tail number

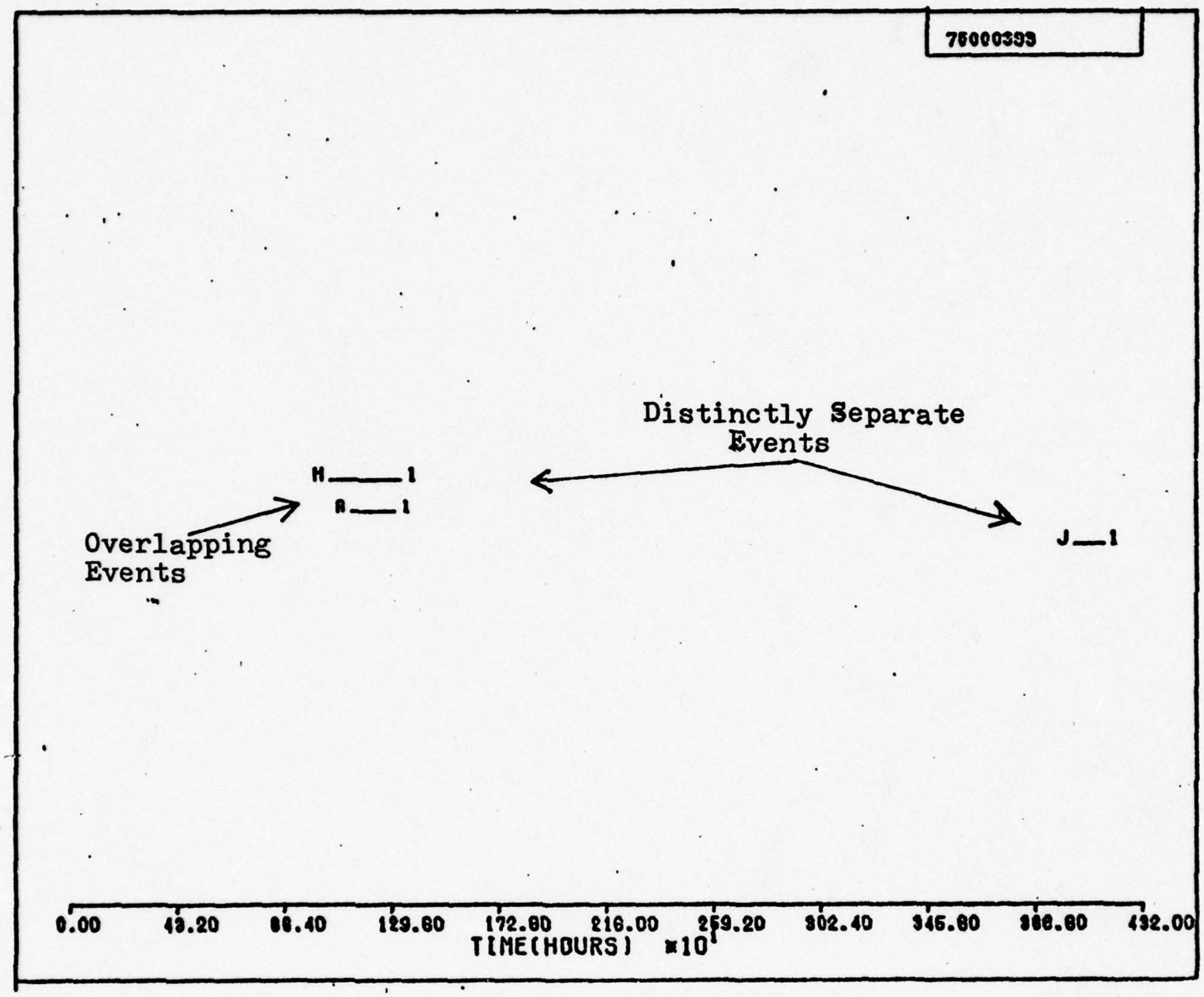

Fig. 11. Overlapping NORS

indicated in upper right hand corner of figure) was grounded for more than one item at the same time. The lines in the figure represent separate NORS occurrences. The occurrence begins at a point in time corresponding to the start of the line and its duration is indicated by the length of the line. The letters correspond to NORS cause codes and the numbers to NORS termination codes (App A).

The appearance of overlapping NORS conditions can be a result of different conditions. First, the overlapping NORS conditions may represent simultaneous failures of items as seen on the right side of Fig. 12. These could be the simultaneous occurrence of unrelated failures, although the likelihood of this is undoubtedly small. A more plausible explanation would be that the random failure of one of the items resulted in the failure of the others. Additionally, these simultaneous events might be the result of crash damage.

A different way in which overlaps could occur is also depicted in Figures 11 and 12. Here, the second NORS occurs some significant amount of time after the occurrence of the first. Recall that these are grounding NORS conditions. Thus, the second NORS occurrence must represent the situation in which an item fails on a non-flyable aircraft; the supply system does not have the needed part. Even if the maintenance facility at the base has enough spare time to perform in depth preventive type maintenance inspections on grounded aircraft, the likelihood of a NORS discovery resulting is

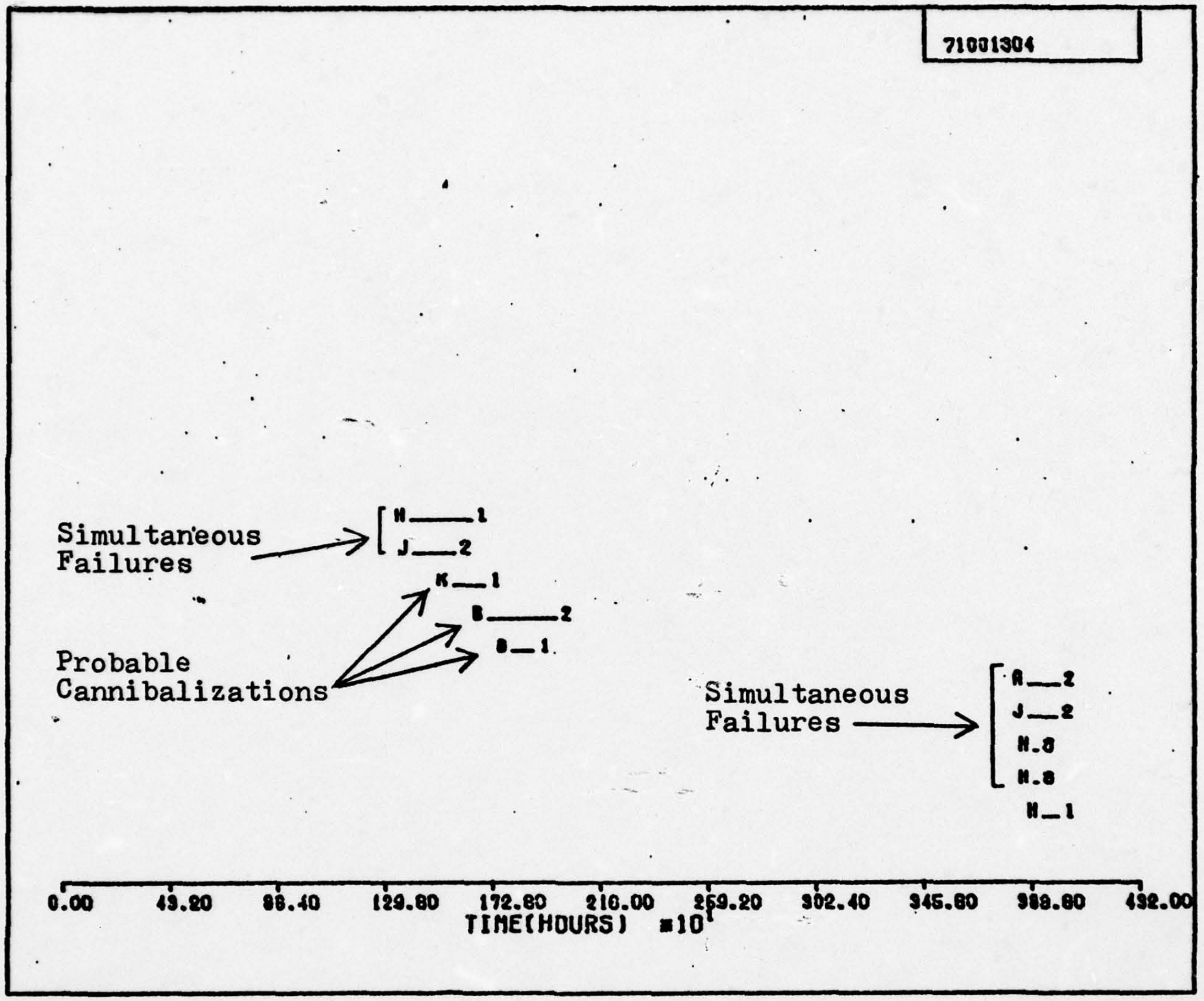

Fig. 12. Overlapping and Simultaneous NORS

still small.

Another explanation for this type of overlap is that the second NORS occurring on the aircraft was a result of a cannibalization on this aircraft to repair another NORS aircraft. It is unlikely that the item would be cannibalized unless the aircraft needing that part was NORS. If another aircraft needed the part but was not NORS, the implication is that the part was reasonably available at the base. Therefore, an overlap like that shown in Fig. 11. very possibly represents a cannibalization. This possibility becomes even stronger when it is noted that cannibalizations comprise 24.6% of the total NORS incidents for the A7 (App A).

NORS data covering the period 1 October 1976 through 31 May 1977 was used to examine the nature of simultaneous and overlapping NORSG events. This data represented 9123 NORSG incidents and a total of 569,839 hours. Because of the overlapping nature of these events as described above, only some fraction of these events and hours would represent actual inoperable aircraft.

The beginning times for NORS events were determined from three data elements in the D165B data base. Using the termination date, the termination hour, and the total hours for which the condition persisted, the NORS history of the A7 was reconstructed. It was from this history that the overlapping NORS lines were constructed. Because of missing information for stop hour and start hour (the start hour was used as an alternative means of discerning the time line),

1200 hours was assumed for approximately 41% of the events. The calculation of time lines was made for both G and F NORS; missing hour codes were found in 4,946 of the 11,970 reports. Additionally, 367 of the records were not used due to the presence of non-numeric data in numeric fields. Using the reconstructed NORS history, the magnitude of simultaneous occurrences was examined. Because of the necessity to estimate the starting hour for such a large fraction of the total NORS, a broad definition of simultaneous events was used in this analysis. Events were said to be simultaneous if the starting time of the second and subsequent events was within 12 hours of the first event. Additionally, events reported as having 0 total hours were considered not to be simultaneous with or to overlap any other event.

After eliminating the records with 0 total hours reported for an event, 4,265 NORSG events remained to be examined. This represented data on 591 different aircraft. The program which examined this data considered each group of simultaneous events as one overlapping event. With the cutoff for simultaneous events set at the 12 hour criterion mentioned above, the following distribution of simultaneous events was noted:

Table VII

Simultaneous NORS

# Simultaneous	# of Occurrences
2	419
3	139
4	45
5	19
6	11
7	6
8	5
9	13
10	3
11	5
12	1
13	0
14	1
.	.
.	.
.	.
18	1

Number of overlaps =1190

The simultaneous events accounted for

$$\sum_{i=2}^{\infty} i \times \# \text{ Occurrences}_i = 2152 \text{ of the} \tag{29}$$

events. Since each simultaneous event counted as one overlap, there were

$$1190 - \left(\sum_{i=2}^{\infty} \# \text{ Occurrences}_i \right) = 716 \tag{30}$$
$$= 474 \text{ non-simultaneous overlaps.}$$

This leaves 4265 - 2152 - 474 = 1639 of the events as non-overlapping, non-simultaneous occurrences.

It was suggested earlier that the 474 non-simultaneous overlapping events represent cannibalization to prevent or end NORS conditions on another aircraft. If this is true, then 474 + 1639 = 2113 of the NORS aircraft could have been repaired by having only one spare part available. This is

equivalent to saying that a reduction in supply NORS of one hour will result in an increase in aircraft availability of 1/2 hour (.495 hours). The assumption inherent here is that the average time to satisfy a requisition for an item involved in a simultaneous occurrence is the same as that required for non-simultaneous events. There is no reason to doubt that this is true. This assumption should not be too restrictive. To violate the assumption, items would have to fail in non-random fashion and all be either out of stock or non-stocked.

This analysis was repeated using 5 hours and 24 hours as the definition for simultaneous events. The results were:

Table VIII

Acft NORS vs Supply NORS

Definition of Simultaneous	Acft NORS hours / Supply NORS hours
5 hrs	.549
12 hrs	.495
24 hrs	.411

The analysis conducted here has been directed at obtaining a better understanding of the relationship between supply NORS and operational aircraft. It has been shown that a reduction of approximately two grounding NORS hours as reported by the supply system will result in an increase in aircraft availability of one hour for the A7D.

CHAPTER VI.

IMPLEMENTING THE METHODOLOGY

Introduction

Thusfar, an expression has been developed which provides a means of estimating the persistent level of NORS items at bases. A method for cost effective application of investment to reduce these NORS was explained. The investigation of the last chapter related item NORS to aircraft NORS. We can now proceed to implement this methodology and examine its potential when used with actual data.

Establishing RCT, NRTS and OST

Recall that expected NORS was a function of OST, RCT, NRTS and DDR. In order to calculate expected NORS, we must establish the value of these parameters. This must be done for each item at each base. The data used to examine the relationship of item NORS to aircraft NORS can be used to simplify the task. Rather than estimate levels and benefit for every reparable item in the inventory, we can restrict the search for investment candidates to those items which caused NORS. Using the eight months of D165 data we used earlier, we can produce a list of items which caused NORS

on the A7D over an eight month period. This list should include almost all items which have a good likelihood of causing NORS. Only those items with low annual expected NORS would not appear on the list. These items would not make good candidates, anyway, since the potential reduction from additional stockage would be relatively small. This method of restricting the search will reduce the computer time required and result in a list of investments which relate to the empirical data.

The method requires that values for the parameters be known for each base. Since there is currently no centralized system for managing base stock levels, the required data is not centrally collected. We must make use of a centralized data source to estimate the required values. The D041 data system provides a means of doing this. The D041 provides values for OST, RCT, and NRTS. In most cases, these values are based on two years of data. Where no data is available, estimates of the values have been included. There should be very little variation in the value of OST among CONUS bases. Similar maintenance capability would be available at all bases so that NRTS and RCT should be practically the same at all bases. Item characteristics would be responsible for the major differences in OST,RCT, and NRTS; these characteristics are the same for all bases and vary only between items. Thus, we will use the D041 values for NRTS, OST and RCT as estimates for each base.

Establishing Daily Demand Rate

Daily demand rate, on the other hand, would exhibit a wider variablility from base to base. Bases which possessed more aircraft would tend to have a higher demand rate for items. Also, bases which had a large flying hour program, but the same number of aircraft would have higher demand rates.

The D041 contains a data element which represents the demand rate per hundred flying hours. This data is an exponential smoothing of information collected for the preceeding two year period (Ref 15). If we know the total flying hour program for a given aircraft type (available from the G033B data system) for a representative period and the fraction of the total aircraft in the fleet which are possessed at a particular base, then we can estimate the base daily demand rate for an item.

$$\lambda_j = \frac{A_j}{\sum A_j} \quad \frac{H}{l} \quad \lambda_f \qquad (31)$$

where λ_j = Daily demand rate at base j

A_j = Number of aircraft at base j

H = Total flying hours for the fleet (hundreds)

l = Length of the period to which H applies

λ_f = Demand per hundred flying hours

λ_f as found in the D041 data base represents failures per installed program hour for a single item. For some items, the quantity per application (QPA) may be greater than one (more than one of the item used on each aircraft). Also, not all items are used on 100% of the fleet. When either of the above cases is true, λ_f should be modified accordingly.

$$\lambda'_f = \lambda_f * QPA * \% \text{ Fleet} \qquad (32)$$

where λ'_f = adjusted demand/flying hour

In order to establish the number of aircraft at any given base, the D165B data may again be used. If we assume that the total fraction of aircraft experiencing NORS in eight months at a base is the same for all bases, then

$$\frac{A_j}{\sum A_j} = \frac{N_j}{\sum N_j} \qquad (33)$$

where N_j = Aircraft reporting NORS in an eight month period. The information for the right hand side of Eq (33) can be had from the D165B simply by counting the number of aircraft reporting NORS by base.

Automated Implementation

By combining data from the D165B, D041 and G033B data systems to determine expected NORS, we can implement the cost effective NORS reduction methodology discussed earlier. Figure 13. is a flow diagram for a system which implements the methodology. The input to the system is the records extracted from the D165B system for the aircraft type under study. From this, the number of aircraft reporting NORS at each base and a list of items causing grounding NORS for the particular aircraft type are determined. The list of potential candidates is used to obtain Unit Price, OST, RRCT, NRTS and Demand per flying hour information from the D041 system. Using this with the aircraft counts at each base, and the flying hours per day for this aircraft type from the G033B, expected NORS can be

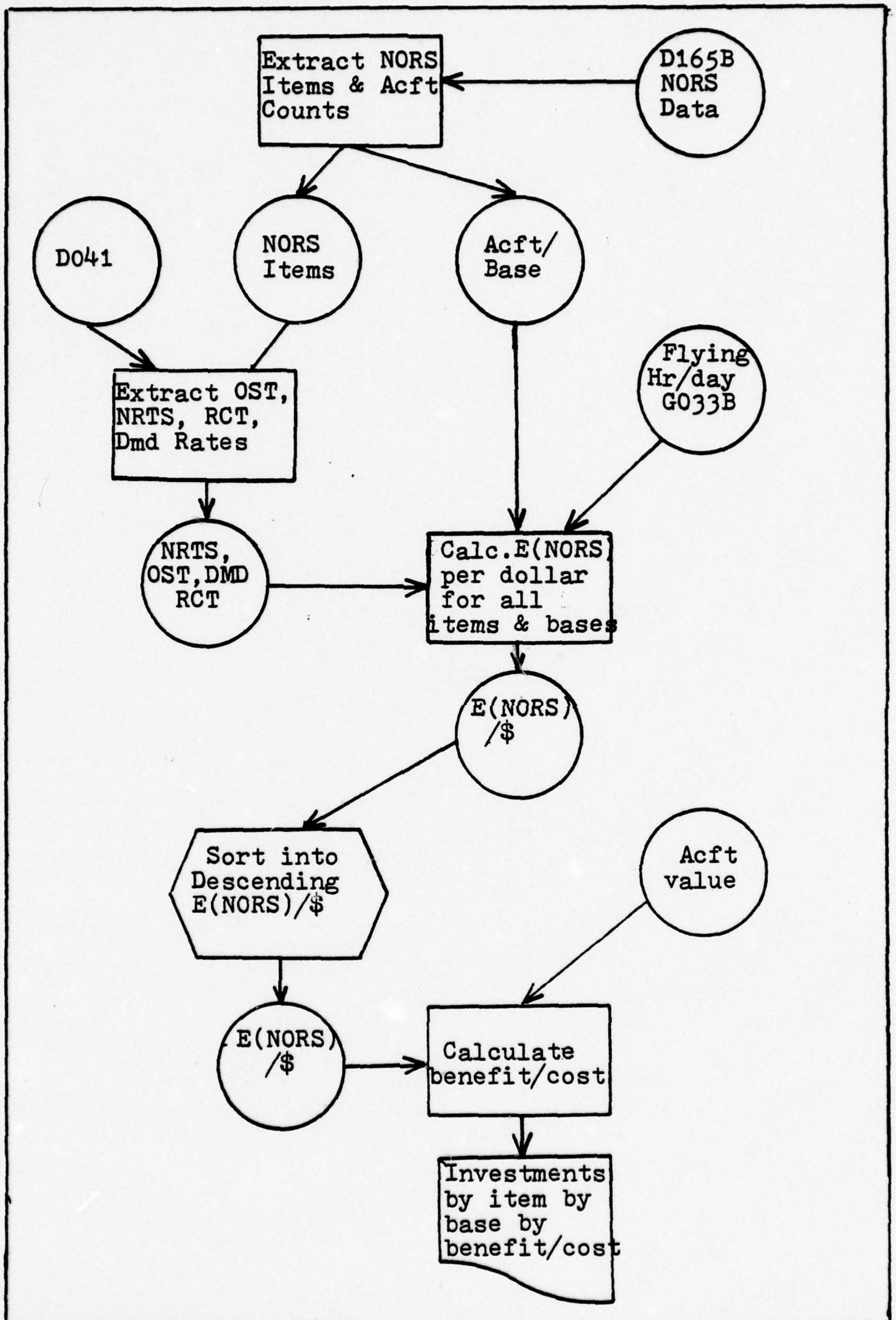

Fig. 13. Flow Diagram-Optimal NORS Reduction Method

calculated. This is done for each item at each base. In order to limit the volume of output, the program which implements this flow chart (App B) ceases to compute expected benefit from additional items when the expected NORS reduction falls below 0.5 days/year. This figure is divided by unit price to obtain a value of this NORS reduction per dollar. Resulting is a file containing NORS reduction per dollar by item by base for adding the first, second, etc., item to the estimated base stockage level. The file is sorted into descending expected NORS reductions per dollar invested sequence. With this sorted file, any level of investment could be made optimally. This would be done by selecting the items from the file sequence and adding an extra item to the authorized level at the indicated base.

Implementation for Multiple Aircraft

The portion of the flow chart in Figure 13 discussed thusfar provides a means of optimal investment. However, it does not provide an appreciation for the return on investment. Such an appreciation becomes important when consideration is given to stocking items for more than one aircraft. In the comparison of item NORS to aircraft NORS, it was seen that the ratio was approximately 2:1. Multiplying the expected NORS reduction per dollar by ½ then provides a better estimate of the true benefit from each dollar invested. This benefit is in terms of additional aircraft days to be had per year for the extra stockage. Dividing by 365 days per year gives a benefit in terms of aircraft per year. This

benefit is approximately what we would expect to gain if we stocked the indicated item at the indicated base for a one year period. If the value of owning an additional aircraft for one year could be estimated, then this would become a multiplier on the benefit and on the benefit to cost ratio.

$$B/C_{ilj} = \frac{0.5\ R_{ilj} W_A}{365\ P_i} \qquad (34)$$

where B/C = benefit to cost ratio for stocking the lth unit of item i at base j

0.5 = ratio of NORS items to NORS aircraft

R_{ilj} = NORS reduction by stocking the lth unit of item i at base j

W_A = the worth of having an additional aircraft of type A for one year

P_i = unit price of item i

So long as only one aircraft type is being considered, W_A can have a value of 1. When multiple aircraft are being considered for additional stockage investment, the values for W_A must be determined.

The values for W_A in the multiple aircraft problem need not be actual values of worth--only relative values of worth. If one of the aircraft under consideration were assigned a worth of 1 and the others assigned worths relative to this aircraft, the optimum ordering of investment cadidates would be insured. Only if one is interested in benefit to cost ratios which are exactly correct, in addition to providing proper investment ordering, need the actual worths be determined.

Improving the Estimates

The method as implemented here assumed that QPA was one and that the items investigated were used on 100% of the fleet.

If the item were actually used on less than 100% of the fleet, the Daily Demand Rate which was calculated would be too high. Likewise, if QPA were actually more than one, the calculated demand rate would be too low. QPA and % of fleet are contained in a section of the D041 data base which was not available for this study. If these data elements were obtained and used, better estimates of Daily Demand Rates and thus benefits could be made.

Bases are identified in the D165B data system only by the supply account code in the document number of the NORS requisitions. If a cross reference of these supply accounts to base names were constructed, the estimates for demand at bases could be improved. By having base names, data could be obtained from the G033B data system which would reflect the average numbers of aircraft possessed at each base. These figures would negate the necessity for estimating the fraction of total aircraft at a base using the relationship in Eq (33). Only those bases which actually have the aircraft type being examined would then be considered for stockage. The system currently used considers bases where aircraft were grounded regardless of whether these aircraft were actually stationed there. Because the number of aircraft involved in these incidents is small when compared to the total number of aircraft, calculated demand rates are extremely small. Thus, for the bases which actually own no aircraft, it is very unlikely that the algorithm would ever recommend additional stockage. Adding the cross reference of bases

to supply accounts discussed here would relieve the necessity for assuming that the proportion of aircraft stationed at a base which experience NORS is constant from base to base.

<u>Adding the Stocks</u>

Recall that predicted improvements are based on estimated base stock levels. The recommendation made by the system is to add one of a particular item to the authorized stock level at a stated base. Buying the part without the accompanying increase in authorized level would result in the item being returned to the depot. Increasing the authorized level without buying an extra item would result in a depletion of depot stocks by one. Presumably, after some delay, the depot would increase its stockage to the old level through procurement. However, during the interim period, increased depot response times might be experienced which would cause degradation at all bases. To avoid this,the item should be purchased at the time the level is increased. If during implementation it is discovered that the level at the base is already at the required level, no additional stockage is required. The base would have already prevented the expected NORS.

We have presented here an automated method for implementation of the methodology. We have also discussed some possible improvements in the estimates and the manner of obtaining the predicted benefits. The potential benefit from implementation of this system will now be examined.

CHAPTER VII.

EXAMINATION OF POTENTIAL

Introduction

Data for this study was collected and examined for different aircraft types. They were the A7, F111, FB111, and B52. The data for a particular aircraft type included all models of that aircraft used by the Air Force. For example, data on the F111 included that concerning the A, D, E, and F models. The items causing grounding NORS on these aircraft during the period 1 Oct 76 through 31 May 77 were examined using the methodology presented in the previous chapters.

Results

Figure 14 shows an output product of the system for the A7 aircraft. This is the first part of a listing of the recommended investment candidates for the A7 in descending sequence of benefit to cost ratio. The benefit is in terms of NORS days per year to be had from stocking the level indicated as the required level (REQ LVL). This benefit is in terms of supply NORS improvements. Approximately 50% of this improvement could be expected in aircraft NORS or readiness. The base where the stocks are to be placed is

SUPPLY ACCOUNT	STOCK NUMBER	NOMENCLATURE	UNIT PRICE	OST	RCT	NRTS	DEMAND RATE	EST LVL	REQ LVL	NORS REDUCTION	IMPROVEMENT PER DOLLAR	TOTAL COST
FB4305	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0048	0	1	20.6053	.299594	69.01
FB4377	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0044	0	1	19.2180	.279482	138.02
FB6311	1630006208670	VALVEASSY	82.00	17	7	82	.0044	0	1	22.0317	.268679	220.02
FB6022	1630006208670	VALVEASSY	82.00	17	7	82	.0042	0	1	20.8093	.253772	302.02
FB6061	1630006208670	VALVEASSY	82.00	17	7	82	.0042	0	1	20.8093	.253772	384.02
FB6540	1630006208670	VALVEASSY	82.00	17	7	82	.0040	0	1	20.1965	.245299	466.02
FB6354	1630006208670	VALVEASSY	82.00	17	7	82	.0039	0	1	19.5925	.239812	548.02
FB4306	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0038	0	1	16.4265	.238033	617.03
FB5381	1630006208670	VALVEASSY	82.00	17	7	82	.0038	0	1	18.9676	.231313	699.03
FB4910	1630006208670	VALVEASSY	82.00	17	7	82	.0035	0	1	17.7344	.216273	791.03
FB5401	1630006208670	VALVEASSY	82.00	17	7	82	.0034	0	1	17.1161	.208733	853.03
FB5260	1630006208670	VALVEASSY	82.00	17	7	82	.0032	0	1	15.8762	.193613	945.03
FB4604	1630006208670	VALVEASSY	82.00	17	7	82	.0029	0	1	14.6320	.179438	1027.03
FB6141	1630006208670	VALVEASSY	82.00	17	7	82	.0025	0	1	12.7572	.155576	1109.03
FB4305	1630006208670	VALVEASSY	82.00	17	7	82	.0200	1	2	12.1175	.147775	1191.03
FB2805	1630006208670	VALVEASSY	82.00	17	7	82	.0021	0	1	10.8724	.132591	1273.03
FB4977	1630006208670	VALVEASSY	82.00	17	7	82	.0187	1	2	10.6336	.129678	1355.03
FB4852	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0018	0	1	7.7861	.112825	1424.04
FK4305	1630006208670	VALVEASSY	82.00	17	7	82	.0018	0	1	8.9776	.109483	1506.04
FK4905	1630006208670	VALVEASSY	82.00	17	7	82	.0018	0	1	8.9776	.109483	1588.04
FB4905	1280002695257	CKT CARD	360.50	43	6	92	.0028	0	1	38.8978	.107872	1948.54
FB2596	1630006208670	VALVEASSY	62.00	17	7	82	.0016	0	1	8.3437	.101753	2030.54
FB5142	1630006208670	VALVEASSY	82.00	17	7	82	.0015	0	1	8.3437	.101753	2112.54
FB4377	1280002695257	CKT CARD	360.50	43	6	92	.0027	0	1	36.3362	.100794	2473.04
FB4906	1630006208670	VALVEASSY	82.00	17	7	82	.0159	1	2	7.9067	.096423	2555.04
FB4806	1280002695257	CKT CARD	360.50	43	6	92	.0023	0	1	31.1730	.086471	2915.54
FB4805	1680007240136LS	PEEL SHLDR	166.20	21	2	89	.0020	0	1	13.7659	.082627	3081.74
FK4377	1630006208670	VALVEASSY	82.00	17	7	82	.0013	0	1	6.4353	.078490	3163.74
FB2923	1630006208670	VALVEASSY	82.00	17	7	82	.0013	0	1	6.4353	.078490	3245.74
FB4877	1680007240136LS	PEEL SHLDR	166.20	21	2	89	.0019	0	1	12.6304	.077199	3411.94
FB5311	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0011	0	1	4.6391	.067223	3480.95
FB4906	1680007240136LS	PEEL SHLDR	166.20	21	2	89	.0016	0	1	10.9521	.065897	3647.15
FB4305	1560004653793MA	SELECTER A	274.80	14	5	85	.0042	0	1	17.9112	.065179	3921.95
FB6061	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0010	0	1	4.3756	.063405	3990.96
FB6022	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0010	0	1	4.3756	.063405	4059.97
FB6311	1660001130098	VALVE	296.60	13	6	89	.0045	0	1	18.7611	.063254	4356.57
FB6540	1680009797782LS	BOTTLE ASY	69.01	14	7	87	.0010	0	1	4.2438	.061495	4425.58
FB4377	1560004653793MA	SELECTER A	274.80	14	5	85	.0039	0	1	16.7008	.060775	4700.38
FB6022	1660001130098	VALVE	296.60	13	6	89	.0043	0	1	17.7155	.059729	4996.98
FB6061	1660001130098	VALVE	296.60	13	6	89	.0043	0	1	17.7155	.059729	5293.58

Fig. 14. Sample Output for A7D

listed on the left as the supply account. The stock number is the Master Stock Number of the item. The column labeled EST LVL is the stock level which the system estimated to be authorized based on the OST, RCT, NRTS and demand rate indicated. The demand rate was that calculated for a particular base.

There are several observations to be made regarding Fig. 14. As would be expected, good investment candidates are those with fairly low unit prices. Also, most of the items at the top of the list have low demand rates. In fact, the system calculated that levels would already exist for only three of the first 40 items. Only 10% of the top 350 investments had values other than 0 for the estimated level. This result is not unexpected. The initial screening of the A7 data indicated that 44.7% of all NORS hours were caused by non-stocked items (App A). Since the demand rates for these items are so low, it is quite conceivable that they were not detected at multiple bases for the eight month history examined. Even though the problem was not reported at multiple bases, the system directs stockage at all bases where it is beneficial to do so. Another factor of interest in Fig. 14. is that the best investments in general have high NRTS rates. The lowest rate found in the top 350 investment candidates for the A7 was 35%.

An appreciation for the potential of this system when applied to a particular aircraft type can be gained by looking at Fig. 15. This figure is a plot of benefit in readiness

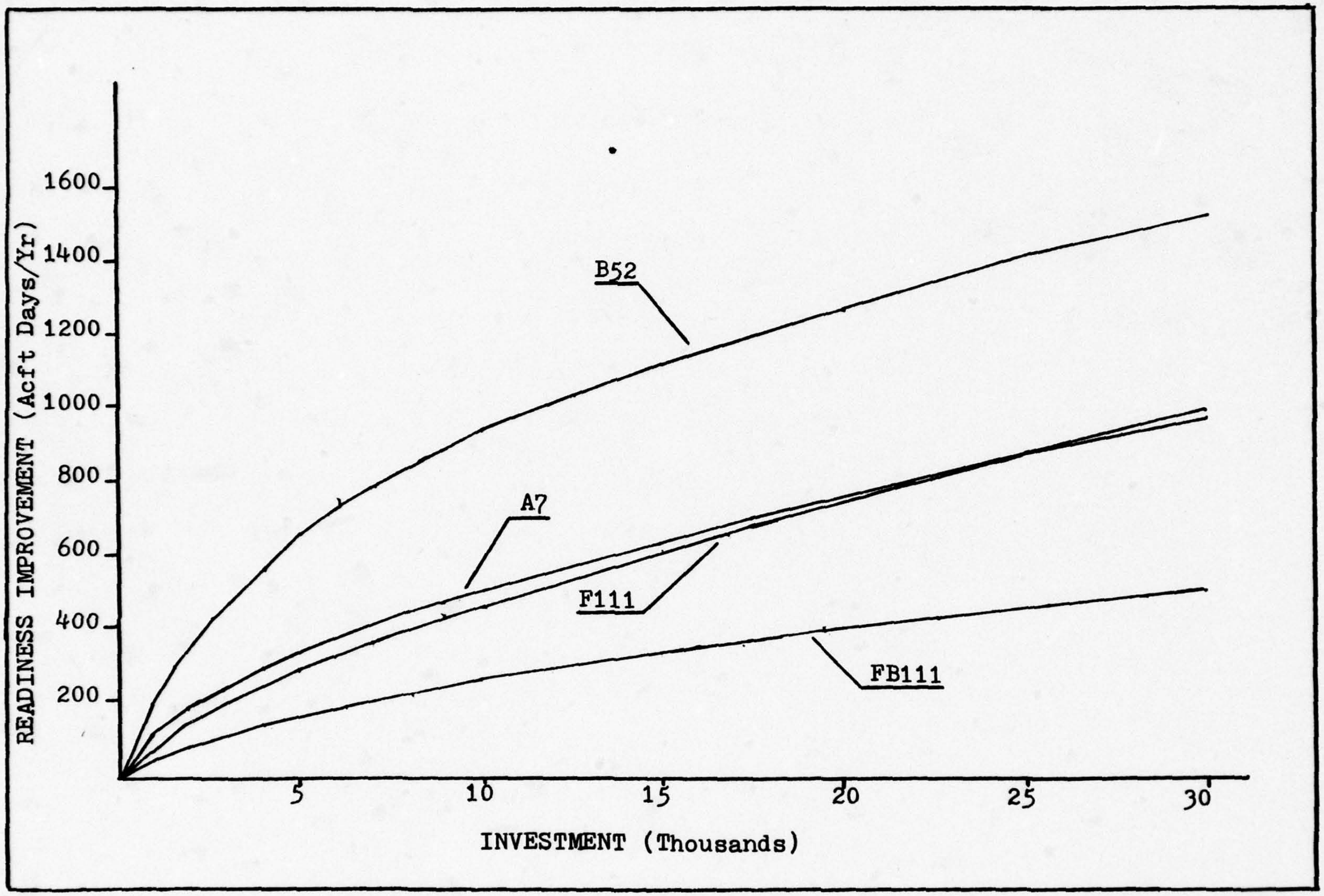

Fig. 15. Benefit vs Investment

terms against investment in additional spares required to obtain that benefit. The benefit in this figure is in terms of additionally ready aircraft days. By investing an amount indicated on the horizontal axis, an increase in aircraft days as indicated on the vertical axis can be expected. For example, by purchasing the first $14,000 worth of the B52 list, a savings of approximately 1100 B52 NORS days/year is possible. The 1100 days of aircraft availability is approximately equal to owning three additional B52's which experience no NORS. If B52's could be purchased for $13.2 million (the average cost of B52G and B52 H) (Ref 16), then the value of the benefit accrued would be $39.6 million for an investment of only $14,000. This represents a cost to benefit ratio of 2829.

For the other aircraft examined, somewhat less benefit could be gained through additional stocks. The potential for these aircraft, however, was still significant. The FB111 indicated the smallest potential return on a given investment. For an investment of $15,000 in the recommended additional stockage for the FB111, a readiness improvement equivalent to approximately one FB111 could be made. If an FB111 could be purchased for $12.6 million (Ref 16), then this readiness improvement represents a return of $840/dollar invested. Although the benefit to cost ratio is lower, the FB111 still has many attractive investment candidates.

Combined Investment

When the benefits in terms of individual aircraft were examined, the system demonstrated potential. If we desired to improve readiness among all aircraft in an optimal manner, a relative value weighting of aircraft would be required. Although it is not clear that the worth of an aircraft is its purchase price, the costs of the aircraft are one means of assigning relative values. Table IX shows the costs of the aircraft types studied here.

Table IX
Aircraft Costs

Acft	Cost (millions)
A7D	3.0
B52G	12.3
B52H	14.1
F111A	11.0
F111D	13.5
F111E	12.6
F111F	13.8
FB111A	12.6

Combining the data for all four aircraft types and using cost as a measure of worth, Fig. 16. is obtained. It is a plot of dollar value of aircraft gained by a given investment. An investment of $20,000 returns 50 million dollars worth of aircraft to operationally ready status; an investment of $150,000 returns 155 million dollars worth.

Recommendations

The results discussed above indicate that the judicious investment in additional stock at selected bases is a worthwhile approach to readiness improvement. The results

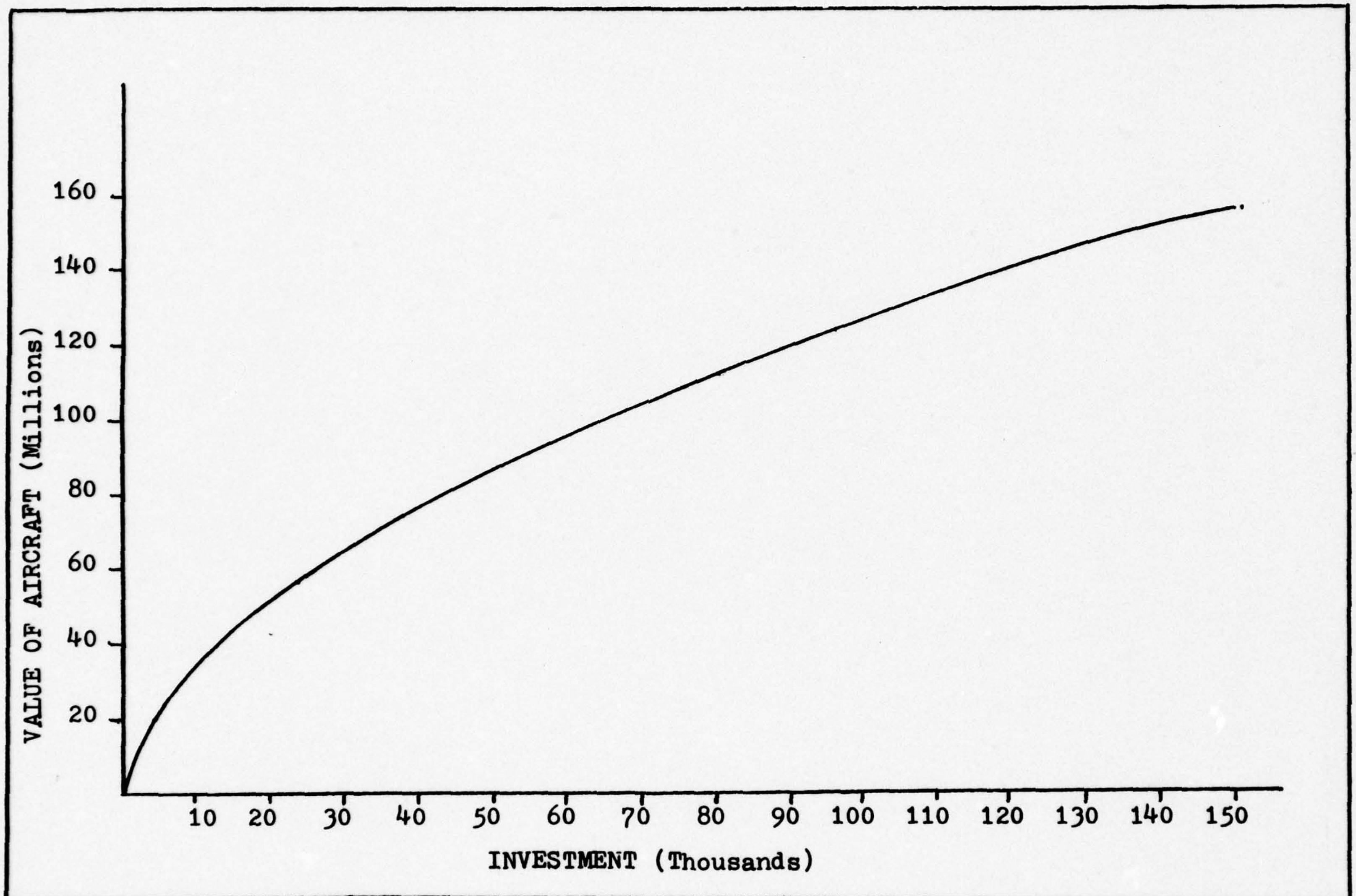

Fig. 16. Combined Benefit vs Cost

presented do not claim to be exact, only to demonstrate potential. Because of this potential, it is recommended that:

1. Data for the refined parameter estimates suggested in Chapter 6 be obtained.

2. A cross reference of supply accounts to bases be included.

3. Data be collected on other aircraft for determination of additional stockage candidates.

4. A test of the system be made. This test could be made as follows: a) select one of the studied aircraft; b) choose two approximately identical bases; c) invest some dollar amount according to the recommended list at one base, using the other base as the Control; d) compare the NORS for the two bases at the end of a specified period.

CHAPTER VIII.

AREAS FOR FURTHER RESEARCH

This study considered only the improvements possible through additional reparable item stockage. It is expected that excellent benefits could be obtained from a similar approach with EOQ items. Because of their relatively lower cost, EOQ items could make even better investments than the reparables. If data for OST and demand rate for EOQ items could be obtained, an approach similar to that developed in this paper could be used.

Another area which warrants additional study is that of leveling the stocks among the bases. If the expected NORS were calculated for stock levels less than the estimated level, this information might be used to obtain benefit for only the redistribution costs involved. By moving stocks one at a time from the base which would be hurt the least to the base which would be helped the most, an optimal redistribution of stocks could be made.

It is conceivable to develop a system for continuous improvement of the NORS situation. If a system for leveling among bases were combined with the optimal stocking method described in this paper, regular improvements could be made.

On a periodic basis (e.g. quarterly), the items causing NORS could be redistributed and additional investment made to minimize the expected NORS at all bases. The base stocking algorithm would continue to function in the background so that bases would be continuously reviewing levels. All of the base levels which indicated a decrease in authorized stocks would be permitted to do so except those for which minimums had been determined by the optimal stockage scheme. Continued application of this method would drive the stock levels at all bases toward an optimum position from a NORS standpoint.

A final area which should be studied is the base stocking policy. The performance of the current base policy as well as alternative policies should be considered. By using various performance measures such as the expected NORS criteria of this paper or the expected backorder criteria of METRIC, a better policy might be found.

CHAPTER XI. SUMMARY

This study has examined the potential for improving readiness by selective investment in additional spares. An examination of the relationship between additional stocks and decreased NORS was made. It was shown that the decrease in NORS from adding stocks could be predicted if the ambient NORS level could be determined. The possibility of deriving the ambient levels from NORS history was examined and rejected. In order to predict the ambient NORS level, an expression for the expected NORS of an item at a base was derived.

Using this expression for expected NORS, a method for predicting the reduction in NORS for an item was developed. This reduction was then related to readiness using eight months of data for the A7D. A marginal allocation technique was described which directed investment in additional stocks to specified bases. This scheme returns the maximum improvement in readiness for each dollar invested.

The method was made operational using information from the D165B, D041, and G033B data systems. It was found that significant improvement in readiness could be had for very small investments in selected reparable spares. The

potential for improving fleet readiness using this procedure is clearly evident. With some refinements, as suggested, this procedure could be implemented quickly and inexpensively.

Bibliography

1. PRAM: Release to Industry. Wright Patterson AFB, Ohio: Aeronautical Systems Division, ASD/RA, Jan 1977.

2. PRAM: First Annual Report. Wright Patterson AFB, Ohio: Aeronautical Systems Division, ASD/RA, Aug 1976.

3. Genet, Russel M., Thomas D. Meitzler and Gordon W. Spray. "Logistics Investment Screening Technique." Unpublished Paper. Wright Patterson AFB, Ohio: PRAM Program Office, ASD/RAX, 19 Aug 1977.

4. Sherebrooke, Craig C. METRIC: A Multi-Echelon Technique for Recoverable Item Control. Santa Monica, Calif.: The RAND Corp., Memorandum RM-5078-PR, Nov 1976. (also published in Operations Research, 16, Jan.-Feb. 1968, pp. 122, 141.).

5. Muckstadt, John A. The Consolidated Support Model (CSM): A Three Echelon, Multi-Item Model for Recoverable Items. Santa Monica, Calif.: The RAND Corp., Report R-1923-PR, Dec 1976.

6. Weifenback, Annette. Base Maintenance Activity and Repair Cycle Times. Santa Monica, Calif.: The RAND Corp., Memorandum RM-5027-PR, Sept 1966.

7. Danforth, Col. Gordon E., personal interview, 21 July 77, System Manager A7D, Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma.

8. U.S.A.F. Supply Manual, Vol I. Air Force Manual 67-1. Washington, D.C.: Department of the Air Force, with changes as of Sept 1977.

9. Presutti, Victor J. and Richard C. Trepp. "More Ado About Economic Order Quantities (EOQ)." Naval Research Logistics Quarterly, Vol 7, No. 2, June 1970, pp.243-251.

10. U.S.A.F. Supply Manual, Vol II. Air Force Manual 67-1. Washington, D.C.: Departmant of the Air Force, with changes as of Sept 1977.

11. Muckstadt, John A. "A Model for a Multi-Item, Multi-Echelon, Multi-Indenture InventorySystem." Management Science, 20. Dec 1973, pp.472-481. (also published as AFLCP 7-13, Sep 1973. LD3119.)

12. Test of a System which Considers the Priority Allocation of Spare Recoverable Components. Washington, D.C.: Logistics Management Institute, LMI Task 73-7, Aug 1974. (LD266236)

13. Hobbs, Jon R., and V.J. Presutti, personal interview, 16 June 1977, Air Force Logistics Command, AFLC/XRS, Wright Patterson AFB, Ohio.

14. Feeney, G.J. and C.C. Sherebrook, "The (s-1,s) Inventory Policy Under Compound Poisson Demand", Management Science, Vol 12, NOS, Jan 1966, pp.391-411.

15. Klevinger, Anita, telephone conversation, 20 Oct-15 Nov 1977, Air Force Logistics Command, AFLC/LORRA, Wright Patterson AFB, Ohio.

16. Unit Cost of Aircraft, Guided Missiles, and Engines. Technical Order 00-25-30. Washington D.C.: Department of the Air Force, 30 Sept 1976.

Supplemental Bibliography

Advanced Logistics System Progress Report FY 71-1. Wright Patterson AFB, Ohio: HQ Air Force Logistics Command, 31 Oct 1970.

Arendell, Russell W. and Lykes S. Henderson, Jr. *MOD-METRIC Tested for Bias.* Unpublished thesis. WPAFB: Air Force Institute of Technology, March 1973.(AD760081)

Brooks, Rolin B.S., Colleen A. Gillen and John Y. Lu. *Alternative Measures of Supply Performance: Fills, Backorders, Operational Rate, and NORS.* Santa Monica, California: the RAND Corp., Rm 6094 PR, Aug 1969. (LD23131)

Executive Summary of Aircraft Reliability, Maintainability, Availability Design Analysis Model (ARMADA). Quantico, Virginia: U.S. Naval Systems Analysis Office, WSAO-R-70-3. (LD25148)

Extension of LMI Developed Model to Generate Air Force Budgets and Fund Allocation Procedures Which Take into Account Weapon System Essentiality. Unpublished. Wasington, D.C.: Logistics Management Institute, SD-321-46 (Task 76-5). (LD 36658M)

Feeney G.J. *S-1 , S Inventory Policy Under Compound Poisson Demand: A Theory of Recoverable Item Stockage.* Santa Monica, Calif.: The RAND Corp., RM-4176-PR, Sept 64 (LD 07397)

Lu, J. *An Aggregate Stockage Policy for EOQ Items at Base Level.* Santa Monica, Calif.: The RAND Corp., RM-5678-PR, Jun 68. (LD 18581)

Measurements of Military Essentiality. Washington, D.C.: Logistics Management Institute, Task 72-3, Aug 1972.

Model to Consider Military Essentiality in the Development of Procurement Plans and Budgets for Recoverable Components. Washington, D.C.: Logistics Management Institute, Task 73-7, Aug 74. (LD26623MC)

Miller, B. *Unconstrained Optimization in the Integers.* Santa Monica, Calif.: The RAND Corp.,RM-6165-PR, Jan 70. (LD24680)

Miller, B. *A Multi-Item Inventory Model with a Joint Backorder Criterion.* Santa Monica, Calif.: The RAND Corp., RM-5901-PR, Apr 69. (Ld24025)

Monthly NORS (Not Operationally Ready-Supply) Model. General Dynamics, Convair Division, CASD-AFS75-008, April 75. (LD 33941A)

Muckstadt, John A. Some Approximations in Multi-Item, Multi-Echelon Inventory Systems for Recoverable Items. Santa Monica, Calif.: The RAND Corp., Paper p-5763, Dec 1976.

-----. Recoverable Inventory Control Using MOD-METRIC. Wright Patterson AFB, Ohio: Air Force Logistics Command, AFLCP 57-13, Sep 1973.

Palm, C. "Analysis of the Erlang Traffic Formula for Busy Signal Arrangements." Ericsson Technics, 5, 1938, pp. 39-58.

Presutti, V. A Proposed Modification to the Criteria for Selecting Critical Items. Wright Patterson AFB, Ohio: Air Force Logistics Command, OA Tech Memo No. 12, Oct 70. (LD25390)

-----. New Approach to NORS (Not Operationally Ready, Supply) Standards. Wright Patterson AFB, Ohio: Air Force Logistics Command, OA Tech Memo No. 13, Dec 70. (LD 25390A)

Scherebrook, C. Multi-Echelon Technique for Recoverable Item Control--Description of the Computer Program for METRIC. Santa Monica, Calif.: The RAND Corp., RM-5882-PR, Mar 69. (LD19700)

-----. MINE: Multi-Indenture Evaluator. Santa Monica, Calif.: The RAND Corp., RM-5826-PR, Dec 68. (LD19355)

Simon, R.M. Waiting Time Till Service for a Simple Inventory Model. Santa Monica, Calif.: The RAND Corp., RM-5927-PR, Mar 69. (LD24026)

-----. Stationary Properties of a Two-Echelon Inventory Model for Low Demand Items. Santa Monica, Calif.: The RAND Corp., RM-5928-PR, May 69. (LD23019)

Smith, Jack W., et.al. Model to Allocate Repair Dollars and Facilities Optimally. Washington, D.C.: Logistics Management Institute, LM-74-9, Aug 74. (LD31634MA)

APPENDIX A

NORS Summary Data

This appendix contains summary information on NORS incidents for five different aircraft types. Tables X and XI provide the key for interpreting the NORS summary tables which follow. NORS cause codes are automatically assigned by the base computer when a NORS requisition is passed to the depot. Termination codes are similarly assigned when the required item is obtained. The termination codes are determined from the routing identifier code (RIC) on the documentation received with the item. An explanation of the logic used in assigning the codes can be found in AFM 67-1 (Ref 10: 6-101, 6-102).

The data collected here was tallied from the D165B data tapes while they were being converted to CDC format. Approximately 5% of the original data was unusable due to alphabetic entries in numeric fields.

Table X

NORS Cause Codes

A	No stock level established--no demand of reparable prior to this request. This code is assigned to change/transfer of stop cards under program control when type stock record account is E or K.
B	No stock level established--past demand or reparable generation experience but AF base stockage policy precludes establishing a level.
C	Item manager/system manager will not authorize a level.
D	Base decision not to stock level.
F	Full base stock--depth of stock insufficient to meet NORS/ANORS/Due-out requirement.
G	Full base stock, quantity necessary to satisfy this requirement is in AWP status.
H	Less than full base stock--stock replenishment requisition exceeds priority group UMMIPS standards.
J	Less than full base stock--stock replenishment requisition does not exceed priority group UMMIPS standareds.
K	Less than full base stock--no due-in established.
R	Full base stock--assets cannot be used to satisfy this requirement; i.e. DIFM in process, deployed MSK, or inaccessible supply point balance.
Y	Data not available on manually prepared stock cards due to computer down for unscheduled maintenance.
Z	System/Commodity received without NORS/ANORS item (initial shortage).

Table XI

NORS Delete (Termination) Code

1	Received from ALC
2	Received from DSA/Other services
3	Satisfied through lateral support
4	Cannibalization used to preclude the NORS occurrence
5	Receipt of base procured item
6	Received from base assets
7	WRM asset has been used to meet the requirement
8	Cannibalization used to satisfy the NORS requirement
9	Reported in error
0	Cancellation of NORS when codes 1-9 do not apply

Table XII

F111 Data Summary

Category	Occurrences	%	Hours	%	Hrs/Occ
GNORS	21302	94.9	967412	87.5	45.4
FNORS	1152	5.1	138130	12.5	119.9
Total	22454		1105542		49.2
Terminations					
1	3319	14.8	662200	59.9	199.5
2	1185	5.3	172360	15.6	145.5
3	441	2.0	30202	2.7	68.5
4	3700	16.5	0	0.0	0.0
5	27	0.1	5397	0.5	199.9
6	281	1.3	33358	3.0	118.7
7	10977	48.9	11769	1.1	1.1
8	1446	6.4	123219	11.1	85.2
9	599	2.7	0	0.0	0.0
0	479	2.1	67037	6.1	140.0
Cause Codes					
A	2266	10.1	224069	20.3	
B	1946	8.7	156156	14.4	
C	0	0.0	0	0.0	
D	0	0.0	0	0.0	
F	4	0.0	404	0.0	
G	4621	20.6	6193	0.5	
H	9707	43.2	578951	52.4	
J	2319	10.3	83987	7.6	
K	1333	5.9	32587	2.9	
R	242	1.1	21096	1.9	
Y	0	0.0	0	0.0	
Z	16	0.0	2099	0.2	

Table XIII

FB111 Data Summary

Category	Occurrences	%	Hours	%	Hrs/Occ
GNORS	2837	69.3	228374	57.2	80.5
FNORS	1259	30.7	170561	42.8	135.5
Total	4096		398935		97.4
Terminations					
1	1451	35.3	197312	49.3	136.0
2	349	8.5	51779	12.9	148.4
3	677	16.5	37260	9.3	55.0
4	52	1.2	0	0.0	0.0
5	21	0.5	3935	1.0	187.4
6	108	2.6	7621	1.9	70.6
7	19	0.5	137	0.0	7.2
8	984	24.0	87167	21.8	88.6
9	280	6.8	0	0.0	0.0
0	164	4.0	15029	3.8	91.6
Cause Codes					
A	971	23.7	85090	21.3	
B	561	13.7	49957	12.5	
C	0	0.0	0	0.0	
D	0	0.0	0	0.0	
F	2	0.0	225	0.0	
G	54	1.3	3192	0.8	
H	1664	40.5	202977	50.7	
J	581	14.2	37549	9.4	
K	124	3.0	10370	2.6	
R	135	3.3	10514	2.6	
Y	0	0.0	0	0.0	
Z	13	0.3	366	0.1	

Table XIV

B052 Data Summary

Category	Occurrences	%	Hours	%	Hrs/Occ
GNORS	11706	50.3	823709	46.8	70.4
FNORS	11572	49.7	936647	53.2	80.9
Total	23278		1760356		75.6
Terminations					
1	8747	37.6	985244	56.0	112.6
2	1468	6.3	180704	10.3	123.1
3	3143	13.5	186403	10.6	59.3
4	617	2.7	0	0.0	0.0
5	236	1.0	11513	0.6	48.8
6	640	2.8	54017	3.1	84.4
7	1944	8.4	809	0.0	0.4
8	5107	21.9	288991	16.4	56.6
9	726	3.0	0	0.0	0.0
0	659	2.8	52891	3.0	80.3
Cause Codes					
A	404	17.3	367427	20.9	
B	2916	12.5	229752	13.0	
C	9	0.0	1419	0.1	
D	4	0.0	337	0.0	
F	6	0.0	1229	0.1	
G	1418	6.1	91002	5.2	
H	9389	40.3	724904	41.2	
J	3907	16.8	231917	13.2	
K	647	2.8	42687	2.4	
R	919	3.9	67074	3.8	
Y	0	0.0	0	0.0	
Z	32	0.1	2824	0.1	

Table XV

A7D Data Summary

Category	Occurrences	%	Hours	%	Hrs/Occ
GNORS	9123	76.0	569839	66.0	62.5
FNORS	2847	24.0	290906	34.0	102.2
Total	11970		860745		71.9
Terminations					
1	2342	19.6	363178	42.2	155.1
2	1452	12.1	231056	26.8	159.1
3	725	6.1	59653	7.0	82.3
4	830	6.9	0	0.0	0.0
5	37	0.3	11499	1.3	310.8
6	247	2.1	25718	3.0	104.1
7	4168	34.8	6010	0.7	1.4
8	1222	10.2	119527	13.9	97.8
9	580	4.8	0	0.0	0.0
0	367	3.1	44104	5.1	120.2
Cause Codes					
A	2349	19.6	258620	30.0	
B	1287	10.7	126581	14.7	
C	0	0.0	0	0.0	
D	0	0.0	0	0.0	
F	2	0.2	335	0.0	
G	1443	12.1	14572	1.7	
H	4466	37.3	289655	33.7	
J	1357	11.3	71230	8.3	
K	617	5.1	24205	2.8	
R	266	2.2	34373	4.0	
Y	1	0.0	171	0.0	
Z	182	1.5	41003	4.8	

Table XVI

C135 Data Summary

Category	Occurrences	%	Hours	%	Hrs/Occ
GNORS	18524	68.2	976468	68.5	52.7
FNORS	8629	31.8	448960	31.5	52.0
Total	27153		1425428		52.5
Terminations					
1	6699	24.6	702144	49.3	104.8
2	2092	7.7	266246	18.7	127.3
3	3940	14.5	207873	14.6	52.8
4	552	2.0	0	0.0	0.0
5	226	1.0	17303	1.2	76.6
6	446	1.6	24470	1.7	54.9
7	8288	30.5	1985	0.1	0.2
8	3574	13.1	145871	10.2	40.8
9	726	2.7	0	0.0	0.0
0	623	2.3	59983	4.2	96.3
Cause Codes					
A	5877	21.6	492433	34.5	
B	4342	16.0	323141	22.7	
C	4	0.0	181	0.0	
D	2	0.0	139	0.0	
F	8	0.0	981	0.1	
G	2948	10.9	33053	2.3	
H	8244	30.3	346357	24.3	
J	4336	16.0	142913	10.0	
K	557	2.0	19536	1.4	
R	814	3.0	60770	4.3	
Y	2	0.0	267	0.0	
Z	32	0.1	6104	0.4	

APPENDIX B

Computer Programs for the Optimal Investment Algorithm

These programs are provided as a basis for continued work using the method presented in this thesis. Following the programs is a sample job stream for implementation on the Control Data Corporation NOS/BE Operating System. The The programs are written so as to be easily combined into larger logical groupings. They were written in small logical steps to permit much of the operation to be performed in an interactive mode where core memory was restricted. The language used was FORTRAN IV EXT.

```
      PROGRAM DAWS1(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE12)
      INTEGER BASE,BASEH,SN,SNH
      CALL SMSORT(74)
      CALL SMFILE("SORT","FORMATTED",5LTAPE1,"REWIND")
      CALL SMFILE("OUTPUT","FORMATTED",5LTAPE2,"REWIND")
      CALL SMKEY(18,1,6,0,"DISPLAY",A)
      CALL SMKEY(35,1,8,0,"DISPLAY",A)
      CALL SMEND
      READ(2,900)BASE,SN
      BASEH=BASE
      SNH=SN
      SNCNT=1.
10    READ (2,900)BASE,SN
      IF(EOF(2).NE.0)GO TO 30
      IF(BASE.NE.BASEH)GO TO 20
      IF(SN.NE.SNH)GO TO 11
      GO TO 10
11    SNCNT=SNCNT+1
      SNH=SN
      GO TO 10
20    WRITE(3)BASEH,SNCNT
      SNTOT=SNTOT+SNCNT
      SNCNT=1
      BASEH=BASE
      SNH=SN
      GO TO 10
30    WRITE(3)BASEH,SNCNT
      SNTOT=SNTOT+SNCNT
      ENDFILE 3
      REWIND 3
      PRINT*,"     SERIAL NUMBER COUNT COMPLETE -- TOTAL OF ",SNTOT," AC
     CFT"
      WRITE(12)SNTOT
      ENDFILE 12
      REWIND 12
      CALL SMSORT(74)
      CALL SMFILE("SORT","FORMATTED",5LTAPE1,"REWIND")
      CALL SMFILE("OUTPUT","FORMATTED",5LTAPE2,"REWIND")
      CALL SMKEY(47,1,15,0,"DISPLAY",A)
      CALL SMEND
35    READ (2,901) CC,MSN1,MSN2,TOTHRS
```

BEST AVAILABLE COPY

```
      IF(EOF(2).NE.0)GO TO 60
      IF(CC.NE."C")GO TO 35
      MSN1H=MSN1
      MSN2H=MSN2
      MSNCNT=1
      XN=1
      TSUM=TOTHRS
      TSUMSQ=TOTHRS**2.
40    READ(2,901)CC,MSN1,MSN2,TOTHRS
      IF(EOF(2).NE.0)GO TO 60
      IF(CC.NE."C")GO TO 40
      IF(MSN1.NE.MSN1H.OR.MSN2.NE.MSN2H)GO TO 50
      XN=XN+1.
      TSUM=TOTHRS+TSUM
      TSUMSQ=TSUMSQ+TOTHRS**2.
      GO TO 40
50    MSNCNT=MSNCNT+1
      XBAR=TSUM/XN
      IF(XN.EQ.1.)GO TO 55
      VAR=(TSUMSQ-TSUM**2./XN)/(XN-1.)
      GO TO 56
55    VAR=0.
56    WRITE(4) MSN1H,MSN2H,XBAR,VAR,XN,TSUM
      XN=1
      TSUM=TOTHRS
      TSUMSQ=TOTHRS**2.
      MSN1H=MSN1
      MSN2H=MSN2
      GO TO 40
60    XBAR=TSUM/XN
      VAR=(TSUMSQ-TSUM**2./XN)/(XN-1.)
      WRITE(4)MSN1H,MSN2H,XBAR,VAR,XN,TSUM
      ENDFILE 4
      PRINT*
      PRINT*," A TOTAL OF ",MSNCNT," MSN'S CAUSED GNORS ON THIS ACFT"
      REWIND 4
      STOP
900   FORMAT(17X,A6,11X,A8)
901   FORMAT(A1,45X,A10,A5,2X,I6)
      END
```

```
      PROGRAM DAWS2(INPUT,OUTPUT,TAPE4,TAPE5,TAPE6,TAPE7)
      REAL NRTS
68    READ(4)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      IF(EOF(4).NE.0)GO TO 104
70    READ(5,905)NSN1,NSN2,NOM,UP,BRCT,OST,OFMTDR,NRTS
      IF(EOF(5).NE.0)GO TO 100
      IF(NSN1.LT.NSN1H)GO TO 70
      IF(NSN1.EQ.NSN1H)GO TO 75
      IF(NSN1.GT.NSN1H)GO TO 80
75    IF(NSN2.LT.NSN2H)GO TO 70
      IF(NSN2.EQ.NSN2H)GO TO 90
      IF(NSN2.GT.NSN2H)GO TO 80
      STOP "ABEND 2"
80    WRITE(6)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      READ(4)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      IF(EOF(4).NE.0)GO TO 104
      IF(NSN1H.EQ.NSN1.AND.NSN2H.EQ.NSN2)GO TO 90
      GO TO 70
90    WRITE(7)NSN1H,NSN2H,XBAR,VAR,XN,TSUM,NOM,UP,BRCT,OST,OFMTDR,NRTS
      GO TO 68
100   WRITE(6)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      READ(4)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      IF(EOF(4).EQ.0)GO TO 100
104   ENDFILE 6
      REWIND 6
      ENDFILE 7
      REWIND 7
      STOP
905   FORMAT(A10,A5,A10,F9.2,F3.0,F2.0,F5.4,F3.2)
      END
```

```
      PROGRAM DAWS3(INPUT,OUTPUT,TAPE3,TAPE7,TAPE8,TAPE12)
      REAL NRTS
      DIMENSION D(11),ANORS(11)
      INFIN=10
      READ (12) SNTOT
      READ*,FHPD
110   READ(7)NSN1H,NSN2H,XBAR,VAR,XN,TSUM,NOM,UP,BRCT,OST,OFMTDR,NRTS
      IF(EOF(7).NE.0)GO TO 150
      IOST=OST
      INRTS=NRTS*100.
      IRCT=BRCT
      REWIND 3
112   READ(3) BASEH,SNCNT
      IF(EOF(3).NE.0)GO TO 110
      BSESZE=SNCNT/SNTOT
      DDRA=OFMTDR*FHPD*BSESZE
      CON=(NRTS*OST+(1.-NRTS)*BRCT)*DDRA
      IF(CON.LT.0.)STOP "NEG CON"
      XLVL=CON+SQRT(3.*CON)
      LVL=XLVL+.5
      IF(DDRA.LT.0.0054)LVL=0
      XLVL=LVL
      LVLOLD=LVL
      P=DDRA*NRTS*OST
      IF(P.LE.0)GO TO 930
      Q=EXP(P)
      I=0
116   I=I+1
      LVL=LVL+I-1
      ENORS=0.
      DO 120 J=1,INFIN
      XLN=LVL+J
      ILN=XLN
      XN=J
      C1=XN*P**XLN
      C2=Q*FACT(ILN)
```

BEST AVAILABLE COPY

AD-A050 765   AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC   F/G 14/1
IMPROVING READINESS: A COST-EFFECTIVE APPROACH.(U)
DEC 77   D D DAWSON

UNCLASSIFIED   AFIT/GOR/SM/77D-4   NL

2 OF 2
AD
A050765

END
DATE
FILMED
4-78
DDC

```
      RAT=C1/C2
      IF(RAT.LT.1.0E-30)GO TO 1211
120   ENORS=ENORS+RAT
1211   ANORS(I)=ENORS*365.
      IF(I.LT.2)GO TO 116
      IF(I.GT.11)GO TO 121
      D(I-1)=ANORS(I-1)-ANORS(I)
      IF(D(I-1).GE.0.5)GO TO 116
      D(11)=I-1
      IF(D(11).LT.1.)GO TO 112
      ID=D(11)
      IF(ID.LE.10)GO TO 122
121   PRINT 906,NSN1H,NSN2H
      ID=10
122   CONTINUE
      DO 130 K=1,ID
      LEVREQ=LVLOLD+K
      IF(UP.GT.0)GO TO 124
      ENPDOL=99999.
      GO TO 130
124   ENPDOL=D(K)/UP
130   WRITE(8)NSN1H,NSN2H,NOM,UP,TSUM,D(K),ENPDOL,LVLOLD,LEVREQ,
     CBASEH,DDRA,IOST,INRTS,IRCT,ANORS(1)
      GO TO 112
150   ENDFILE 8
      REWIND 8
      STOP
906   FORMAT(//,1X,"STOCK # ",A10,A5," COMPUTED MORE THAN 10 ADX ITEMS")
907   FORMAT(/,1X,"UNABLE TO COMPUTE NORS FOR ",A10,A5," DDRA= ",F5.3,
     C" NRTS= ",F5.3," OST = ",F6.2)
930   PRINT 907,NSN1H,NSN2H,DDRA,NRTS,OST
      GO TO 110
      END
      FUNCTION FACT(III)
      FACT=1.
      IF(III.EQ.0)RETURN
      DO 10 I=1,III
      X=I
10    FACT=FACT*X
      RETURN
      END
```

BEST AVAILABLE COPY

```
PROGRAM SRT8(INPUT,OUTPUT,TAPE8,TAPE10)
REWIND 8
CALL SMSORT(150)
CALL SMFILE("SORT","BINARY",5LTAPE8,"REWIND")
CALL SMFILE("OUTPUT","BINARY",6LTAPE10,"REWIND")
CALL SMKEY(61,1,10,0,"FLOAT","D")
CALL SMEND
REWIND 10
STOP
END
```

```
      PROGRAM DAWS4(INPUT,OUTPUT,TAPE9,TAPE10)
5     KNT=0
      PRINT 101
      PRINT 102
      PRINT 103
10    READ (9) NSN1H,NSN2H,NOM,UP,TSUM,DIF,ENPDOL,LVLOLD,LEVREQ,
     CBASE,DDRA,IOST,INRTS,IRCT
      IF(EOF(9).NE.0)GO TO 33
      CUM=CUM+UP
      PRINT 104,BASE,NSN1H,NSN2H,NOM,UP,IOST,IRCT,INRTS,DDRA,LVLOLD,LEVR
     CEQ,DIF,ENPDOL,CUM
      KNT=KNT+1
      KNTTOT=KNTTOT+1
      IF(KNTTOT.EQ.800)GO TO 33
      IF(KNT.EQ.40)GO TO 5
      GO TO 10
33    CUM=0.
      READ*,BUDGET
34    KNT=0
      PRINT 101
      PRINT 102
      PRINT 103
40    READ(10) NSN1H,NSN2H,NOM,UP,TSUM,DIF,ENPDOL,LVLOLD,LEVREQ,
     CBASE,DDRA,IOST,INRTS,IRCT
      IF(EOF(10).NE.0)STOP
      CUM=CUM+UP
      TOTRED=TOTRED+DIF
      PRINT 104,BASE,NSN1H,NSN2H,NOM,UP,IOST,IRCT,INRTS,DDRA,LVLOLD,LEVR
     CEQ,DIF,ENPDOL,CUM
      IF(CUM.GE.BUDGET)GO TO 50
      KNT=KNT+1
      IF(KNT.EQ.40)GO TO 34
      GO TO 40
50    PRINT*
      PRINT*," BUDGET LIMIT REACHED"
      PRINT*," TOTAL EXPECTED NORS HOUR REDUCTION = ",TOTRED
101   FORMAT(1H1,//)
102   FORMAT(1X,"SUPPLY",6X,"STOCK",23X,"UNIT",22X,"DEMAND  EST  REQ
     CNORS HOUR   IMPROVEMENT","    TOTAL")
103   FORMAT(1X,"ACCOUNT",5X,"NUMBER",6X,"NOMENCLATURE",4X,"PRICE",4X,"
     COST  RCT   NRTS   RATE  LVL  LVL    REDUCTION   PER DOLLAR","
     CCOST")
104   FORMAT(1X,A6,2X,A10,A5,2X,A10,2X,F10.2,2X,I3,2X,I3,3X,I4,2X
     C,F6.4,2X,I2,3X,I2,4X,F8.4,3X,F10.6,F13.2)
      END
```

BEST AVAILABLE COPY

```
      PROGRAM DAWS5(INPUT,OUTPUT,TAPE6)
5     KNT=0
      PRINT 500
      PRINT 501
      PRINT 502
      PRINT 503
10    READ(6)NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      IF(EOF(6).NE.0)STOP
      PRINT 504,NSN1H,NSN2H,XBAR,VAR,XN,TSUM
      KNT=KNT+1
      IF(KNT.GT.40)GO TO 5
      GO TO 10
500   FORMAT(1H1,///)
501   FORMAT(24X,"STOCK NUMBERS NOT ON D041 FILE",/)
502   FORMAT(10X," STOCK NUMBER    MEAN",17X,"NUMBER OF  TOTAL")
503   FORMAT(27X,"NORS HRS   VARIANCE  INCIDENTS  HOURS",/)
504   FORMAT(10X,A10,A5,2X,F8.2,2X,F9.2,5X,F3.0,5X,F8.0)
      END
..
```

```
DDD,T85Ø,IO85Ø,MT1,CM75ØØ4,STCSA.  A75Ø561,CENET,57201
LIBRARY,COBOL.
RFL,75ØØØ.
ATTACH,D1,PRAMCBR,CY=1.
FTN,I=D1,L=Ø.
LABEL,TAPE1,R,L=B052SORTEDNORS,VSN=LØ5944,NORING.
LGO.
RETURN,LGO.
REWIND,TAPE3.
REWIND,TAPE4,TAPE12.
UNLOAD,TAPE1.
RETURN,D1,TAPE2.
ATTACH,D2,PRAMCBR,CY=2.
FTN,I=D2,L=Ø.
LABEL,TAPE5,R,L=DØ41EXT,VSN=LØ6Ø85,NORING.
RETURN,D2.
LGO.
RETURN,LGO.
REWIND,TAPE6,TAPE7.
RETURN,TAPE5,TAPE4.
ATTACH,D3,PRAMCBR,CY=3.
FTN,I=D3,L=Ø.
RETURN,D3.
LGO.
RETURN,LGO.
REWIND,TAPE8.
RETURN,TAPE3,TAPE7,TAPE12.
ATTACH,SRT,PRAMCBR1,CY=5.
FTN,I=SRT,L=Ø.
RETURN,SRT.
LGO.
RETURN,LGO.
ATTACH,D4,PRAMCBR,CY=4.
REWIND,TAPE1Ø.
FTN,I=D4,L=Ø.
RETURN,D4.
LGO(PL=1ØØØØ)
RETURN,LGO.
RETURN,TAPE8,TAPE1Ø.
ATTACH,D5,PRAMCBR,CY=5.
FTN,I=D5,L=Ø.
..
```

```
RETURN,D5.
LGO(PL=10000)
RETURN,LGO.
RETURN,TAPE6.
REWIND,INPUT.
COPYBF,INPUT.
EXIT,S.
ROUTE,TAPE3,TID=X7,FID=TAPE3,DC=PR.
ROUTE,TAPE4,TID=X7,FID=TAPE4,DC=PR.
ROUTE,TAPE6,TID=X7,FID=TAPE6,DC=PR.
ROUTE,TAPE7,TID=X7,FID=TAPE7,DC=PR.
ROUTE,TAPE8,TID=X7,FID=TAPE8,DC=PR.
ROUTE,TAPE10,TID=X7,FID=TAP10,DC=PR.
REWIND,INPUT.
COPYBF,INPUT.
*EOR
2.9863
*EOR
B-52
13.2
..
```

VITA

David Dean Dawson was born 13 October 1947 in Parkersburg, West Virginia. Upon graduation from Parkersburg High School in June 1965, he enlisted in the U.S. Army. In 1970, he received a B.S. degree from the United States Military Academy, West Point, New York. Since then, he has served in various assignments in the U.S. and RVN, including 2½ years as a data processing officer. He is a graduate of the Army Jump School, Ranger School, Signal Officer's Course, ADP Officer's Course and the USMC Advanced Communications Officer's Course. While attending the Air Force Institute of Technology (June 1976-December 1977), he was elected to Tau Beta Pi, Engineering Honor Society.

Permanent address: Rt. 1, Box 138
Grantsville, West Va.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

(14) (9) READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER AFIT/GOR/SM/77D-4	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER Master's thesis	
4. TITLE (and Subtitle) (6) IMPROVING READINESS: A COST-EFFECTIVE APPROACH.	5. TYPE OF REPORT & PERIOD COVERED MS THESIS
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Dean David [redacted] Dawson Captain USA	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Institute of Technology Wright-Patterson AFB, OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Institute of Technology Wright-Patterson AFB, OH 45433	(11) 12. REPORT DATE Dec[redacted]77 13. NUMBER OF PAGES 105 (12) 105p.
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Approved for public release; IAW AFR 190-17

Jerral F. Guess

JERRAL F. GUESS, Captain USAF
Director of Information

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

NORS
Operational Readiness
Readiness
Marginal Analysis
Aircraft Availability
Not operationally ready supply

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis develops and demonstrates a method for improving aircraft readiness by adding specific stocks to specific bases. The effect of additional stockage on (NORS) is discussed. The relationship of items requisitioned as NORS to NORS aircraft is investigated using eight months of reported NORS for the A7D. Using an expression for expected NORS which is developed in the paper, a method for improving readiness is presented. The potential of the method is demonstrated using data on the F111, FB111, A7D, and B52.

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

012 225

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

Increases in readiness equivalent to several additional aircraft are shown to be possible for relatively very low investments. A summary of eight months of NORS data for the F111, FB111, A7D, B52 and C135 is also included.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)